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PSYCHOLOGY AND THE PROBLEM OF RELIABILITY OF THE RAILROAD
10 OCTOBER 1980 ENGINEER BY L. S. NERSESYAN AND O. A. KONOPHIN 3/ 1 OF 1

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USSR Report

LIFE SCIENCES

BIOMEDICAL AND BEHAVIORAL SCIENCES

(FOUO 3/80)

Psychology and the Problem
of Reliability of the Railroad Engineer

By

L.S. Nersesyan and O.A. Konopkin



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PSYCHOLOGY AND THE PROBLEM OF RELIABILITY
OF THE RAILROAD ENGINEER

Moscow INZHENERNAYA PSIKHOLOGIYA I PROBLEMA NADEZHNOСТИ MASHINISTA
in Russian 1978 signed to press 25 Aug 78 pp 33-45

[Book by L.S. Nersesyan and O.A. Konopkin, Izdatel'stvo Transport,
5,100 copies, 240 pages]

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CHAPTER 2. ANALYSIS OF WORK OF A RAILROAD ENGINEER

Moscow INZHENERNAYA PSIKHOLOGIYA I PROBLEMA NADEZHNOСТИ MASHINISTA in Russian 1978 signed to press 25 Aug 78 pp 33-45

[First section of Chapter 2 from the book "Inzhenernaya psikhologiya i problema nadezhnosti mashinista" by L. S. Nersesyan and O. A. Konopkin, Izdatel'stvo Transport, 5100 copies, 240 pages]

[Text] Psychological Analysis of the Railroad Engineer Occupation
(Professiogram)

The specifics of concrete forms of labor make certain demands with regard to general and more particular psychophysiological and psychological traits and qualities of a worker, the presence of which determines the professional fitness for a given occupation. Consequently, in order to predict the fitness or unfitness of an individual for a given type of work one must make a special analysis of this work. Analysis and objective description of an occupation, which reflect rather thoroughly its distinctive features are called a professiogram.

When the individual distinctions of man coincide with the professiographic requirements, one can state with some degree of probability that the individual is occupationally fit for a given type of labor.

The chief methodological procedures that are currently used in psychological studies of contemporary occupations in general and railroad workers in particular may be observation and qualitative analysis of the structure of performance, as well as other procedures that permit objective recording and quantitative evaluation of the work actions of a working man.

In this section of the chapter, we shall give a general description of the occupation of railroad engineer on a mainline locomotive, and we shall also demonstrate a number of psychophysiological features that are professionally significant and specific to this occupation. In turn, to overcome the difficulties involved in the work of an engineer implies that there are certain psychophysiological prerequisites and raises the question of necessity of occupational screening, development of the

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bases for determining professional fitness of applicants for engineer jobs and, finally, implementation of periodic determination of occupational reliability of professionals who are already working.

A modern locomotive, like other means of transport, is referable to the class of dynamic systems, the work of whose operator is characterized by the existence of two main components of work, performed concurrently, each with its own control system. We refer to the actual driving process (controlling spatial movement of the locomotive) and monitoring the operation of the locomotive's power system (keeping its operation in the normal range). In such cases of "dual" systems, reliability factors are particularly important, since the probability of malfunction is higher when there is parallel performance of several elements of work.

Driving the locomotive, in which observation of the condition of the track occupies a significant place, is a particularly responsible element of engineer work. The very fact that an object that moves in space at high speed is controlled manually, on the basis of periodic or suddenly received information, makes it necessary to constantly refine and correct the subjective model of the environment. Such a model emerges in engineer work as a highly dynamic element, constantly reproduced by the subject, of the process of self-regulation. In other words, the operator-engineer never has a sufficient amount of information about the environment, on the basis of which he could follow a long-term program of his actions to control the system.

Externally, these features of existence of a subjective model of the environment are manifested by the fact that the operator is compelled to constantly observe the condition of the track, tries to detect as early as possible any atypical, but highly significant events in the context of his work.

The power system of the locomotive is the other object of control in the work of an engineer. The engineer perceives informative data about the operation of its units through vision (instrument readings) and hearing (sound of working machinery). In addition, the engineer judges performance of different units according to the vibration of the locomotive body.

The model of electric circuits of the locomotive, in particular those of the high-voltage chamber, is a professionally important information model for the engineer of an electric locomotive. The model of the position of the main relays and contacts in this system becomes the basis for monitoring operation of the machinery. In this case, there is mental reproduction of the object, work with models of objects that are not before the eyes at a given moment. These information models are necessary in case of diverse malfunctions and defects. Since driving cannot be performed without eliminating such defects, it is a mandatory element

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of the engineer's job as a whole to perform such "diagnostic" work when controlling complex objects.

Thus, the engineer, as the "human element" in the control system, must constantly process information, both from the outside and from the controlled object itself, and implement it through controlling actions.

A locomotive engineer emerges as an operator of a rather complex technological system, the objective complexity of which causes the subjective difficulties inherent in the work of an engineer. The most important of them is that the engineer must distribute the direction of his mental processes between performance of two different work elements, that are essentially concurrent, and each of which emerges in some cases to the engineer as an independent form of work, in spite of the fact that they are closely interrelated.

The engineer does not have the opportunity to concentrate for a relatively long period of time on either the process of driving as such, or servicing a unit.

It is necessary for all of his equipment to be in normal condition for successful performance of the different operations related to driving locomotives. The engineer must monitor the condition of a unit and perform actions to service it without losing for a minute his awareness of the road situation and parameters of movement of the train.

The combination of both elements of work imposes some quite serious demands on a mainline locomotive engineer, and it emerges as a significant factor that complicates work as a whole.

Figure 2 illustrates the general flowchart of the control process. It does not show all of the characteristics of the real process of this form of operator activity, since the success of the work of an operator-engineer is largely determined by the subjective state of the operator himself, a combination of objective and subjective elements of his performance. It is quite obvious that it is impossible to assure high reliability of the control system without consideration of the reliability of all its elements.

It is of enormous importance to increase the reliability of control processes performed by the operator-engineer, not only because of the considerable operational work load performed by man, but by virtue of the particularly high requirements for the quality of his professional performance. This is related to the fact that an error he makes cannot be corrected for a number of reasons, or compensated by subsequent control action, while transport accidents are fraught with serious consequences.

We can distinguish two main successive stages in the work of an operator-engineer: preparation of the locomotive for the trip and actual train-running work.

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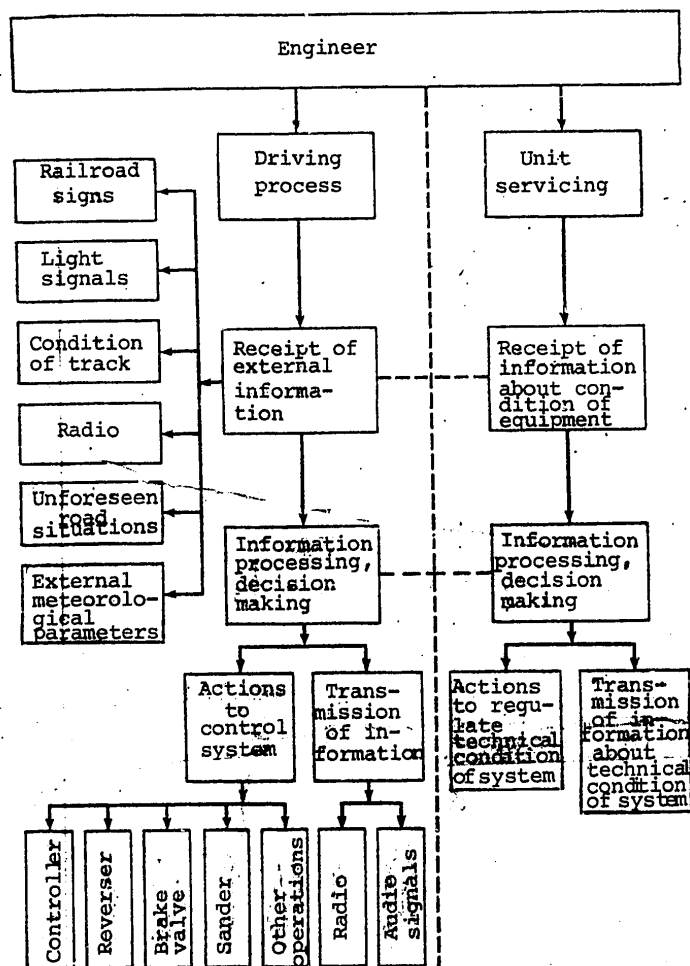


Figure 2. Flowchart of the process of engineer's control of a mainline locomotive

Preparing the locomotive refers to direct inspection thereof when taking it over and in the station. The engineer must make sure the locomotive is in good repair, that there is a supply of sand and lubricants, and check for extraneous noises or knocks in units and parts; he must make sure that the controller, all electropneumatic contacts, lights, etc., work properly.

After the locomotive is coupled to the train, the engineer must check that the locomotive is properly hitched to the first car and air hoses.

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The engineer spends considerable time on this preparatory work, since its quality is a guarantee that the different systems of the locomotive, malfunction of which could lead to serious difficulties during the run, will operate without failure.

The engineer's train-running work imposes high demands with respect to efficiency of the different analyzer systems of the body. This applies, first of all, to the function of the visual, motor and auditory analyzers. Because of the short time available for control actions, which is related, in particular, to the objective restrictions on braking distance, the engineer must, within an extremely short time, not only perceive the necessary signal, but interpret it properly, make the appropriate decision and implement it in the form of the required motor act. In this respect, function of the visual analyzer acquires special importance.

The track is the object of the engineer's main attention. While running the train, the engineer continuously receives information about the condition of the track, track signals, area near the track and moving objects, which are of some importance to safe movement (pedestrians, vehicles at railroad crossings, etc.).

There is a rather large volume of such information. An estimate of signaling stimuli to which an engineer is exposed during a 600-km run revealed that they constitute a total of 8 to 10 thousand, only 10% of which are important (light signals, crossings, speed limit signs, road ["profile"] signs, etc.) The others, while not of prime importance, can become so at any moment. This means that even at "moderate" speeds for modern railroad transport (80-100 km/h), an engineer receives a mean of 20 signal stimuli per min when traveling at 80 km/h and 22-28 at 100 km/h.

Let us recall that on several of the lines in our country, the speed reaches 200 km/h over some segments of the run.

Upon receiving the next piece of information during a run, the engineer performs various manipulations to control the locomotive, in accordance with his experience, operating skill, knowledge of the road "profile" of the section on which he works and, finally, depending on the weather.

One of the main distinctions of engineer work is that, even when he knows his section of track well, he has no guarantee against unpredictable events, the uncertainty of which (including time) is quite great. The inaccuracies and errors made by engineers when running locomotives are related, to a significant extent, to flaws in the subjective model of working conditions, i.e., missing significant signals, as well as to various mistakes in perception of signals and evaluation of their significance.

Analysis of the work place in the cabin of a locomotive engineer and of his operational performance revealed that the movements by which the

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locomotive is controlled are not complicated, and they are characterized by minimal muscular exertion. According to the data of G. V. Daletskaya, overall muscular work of an engineer constitutes 40-50 kg-m in 3-6 h of work when the train travels at 100-140 km/h. In this time, he performs about 650 movements that are insignificant in force. But in some situations, his ability to perform rapid and accurate actions becomes particularly important. Such a necessity arises when there is a sudden change of signals, appearance of obstacles on the track, breakage of trolley wire, drastic change in voltage of the contact [trolley wire] circuit, etc. Some increase in physical exertion is observed on sections where the road features are complicated [curves, grades, etc.]. This is attributable to the fact that when descending from a mountain pass, electric locomotive engineers have to regenerative [power], while diesel locomotive engineers have to use their brakes. Under ordinary conditions, the actions involved in running a locomotive usually consist of several combinations of a limited number of standard motor elements, which do not require great speed, accuracy of gradation or considerable physical effort. Performance thereof does not require any special psychomotor skill. However, in a number of cases, there may be minimal and simplified visual monitoring of performance of actions, when it is hindered by intensive "external" observation, required in particular to obtain information about the control actions already performed as well.

This link between different controlling actions and the equipment controls is implemented by the motor analyzer, which means that it must meet some high and specific requirements.

If we were to single out, in a simplified manner, sensory, cognitive and motor elements in the work of an engineer, the proportion between them is far from equal in the course of train-running work. For example, time studies covering one of the run sections revealed that the engineer handled the controller 13 times, engineer's valve [brake?] 7 times, louver control to regulate water temperature 16 times, and signal whistle 9 times over a 90-km road covered in 50 min during a night run. In all, he performed 45 movements that were necessary and sufficient to run the train and adhere to traffic safety rules.

In this same time, the engineer received 88 track signals important to his work, not counting road signs, speed limit signs, inspector's signals, etc. Concurrently, he watched the instrument readings characterizing movement of the train, operation of the unit and different elements of the locomotive.

The staff of the laboratory of industrial physiology and hygiene of the L'vov railroad conducted time studies of diesel and electric locomotive engineers, and found that 83% of their total work time is spent in a state of so-called "operational rest" [calm].

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Thus, even simple photography of a small segment of train-running work shows that the visual analyzer plays an exceptional part; through it signals and instrument information from the control console of the locomotive are perceived.

The period reports of the engineer's assistant, as well as signals received by the auditory analyzer about the condition of the locomotive engine are one of the forms of information received by the engineer.

As for cognitive [thinking] activity, during a normal run over a familiar road section it cannot be qualified as very intensive, since it is unrelated to formation of new creative decisions and, as a rule, it is only limited to the choice of one out of a small number of familiar decisions.

Not infrequently, prevention of an accident situation depends on the extent to which the engineer can properly gage the distance to an unexpected obstacle. While operators of other forms of transport could, if necessary, drive around an obstacle, a railroad engineer has only one real way to avoid an accident in a similar situation: stop the train. As he approaches a station, the engineer must be concerned not only with avoiding severe jolts, but to stop the train at a very specific place. In this regard, direct estimation of the distance to the stopping place is very important. This applies equally to an open line, where the engineer must "sense" the time and place to start braking on some sections of the road in order to alter the speed of the train as stipulated in the schedule.

Consequently, one of the specific traits in successful performance by an engineer is specialized perception of time and space.

The continuous visual evaluation of different sections of the road, required in the work of an engineer, is often made under extremely adverse conditions, at night, in fog or rainy weather, etc. Visual gaging of distance is particularly important in cases where sudden braking is required. Such visual gaging depends primarily on how accurately the engineer can compare various spatial parameters under normal working conditions.

Specially conducted experiments during train-running work with good visibility and on straight sections of road revealed that the ability to gage distance is unstable, even in experienced engineers. Short distances (100-350 m) are mainly overestimated. Average (350-600 m) and long (600-1000 m) ones are underestimated in most cases.

When visibility is poor and when road conditions [curves, grades] are complicated, such visual estimates are poorer. Under such conditions, the capacity to compare various spatial parameters acquires special importance.

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One of the main concepts related to problems of safety of train movement is the braking distance. When estimating braking distance under specific conditions, objective criteria are considered, which are related to the technical condition of brake mechanisms and length of the track section as related to weight and speed of the train. Psychophysiological analysis of engineer behavior in cases of preventing accidents revealed that the level of readiness of his sensorimotor systems is a significant element determining the optimum braking distance.

When a man performs some work or other, processes take place in his body that lead, at a certain time, to more or less drastic decrease in efficiency, i.e., fatigue.

Fatigue is a complex and diverse phenomenon. It often does not have a direct effect on the result of work, but is manifested in a different way. For example, work operations that were easily performed before, without any tension, "automatically," require additional exertion after working for a few hours, with some voluntary strain on the sensory and motor systems, and special attention. The efficacy of work does not necessarily diminish in such a case, but the effort applied and tension are a symptom of fatigue.

Numerous studies involving recording of accuracy of controlling actions, strength of grasping control levers, magnitude of electromuscular potentials and blood pressure in the course of running a train over the same run revealed that the time and force applied to controls almost doubled after working for 4 h at high speed. Many superfluous movements appear, duration and amplitude of electric biopotential of the brachial biceps increase, mean dynamic blood pressure rises, with concurrent decline of oscillographic index. The longer the train was run at high speed, the more severe were these changes.

One can force oneself to continue working through will power. However, as shown by experience, such work becomes less reliable than the work of an individual who is in an optimum, untired condition.

Rapid and correction reactions of the engineer to a sudden emergency situation are an important feature of high level of fitness and alertness. Readiness for emergency action, i.e., alertness, is the first to diminish under the influence of fatigue. This, in turn, increases significantly the probability of an accident.

Maintaining alertness during night runs is a particular problem. Night work disrupts the circadian rhythm of the body, which developed a specific rhythm of activity and rest in the course of long biological development, that conforms with the alternation of night and day. Any disruption of this rhythm is a substantial burden for the body.

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Aside from disruption of the circadian rhythm, running a train at night involves particular eye strain. At the same time, the number of visible objects diminishes drastically, and this augments the influence of monotony.

The changes in level of alertness due to the effects of constant external factors are cyclic. According to the existing data, man is usually the most active between 1600 and 1700 hours and least active at 0300-0400.

Monotony of work is in itself an inhibitory factor that induces drowsiness and falling asleep. On long runs, in addition to visual and auditory monotony, the engineer is affected by constant vibration that produces a sort of rocking. Nor does hypodynamia help increase wakefulness: seated position, small range of professionally required movements, as well as the ambient temperature in the engineer's cab, which is not at an optimum.

Alertness and quality of performing professional duties diminish already at a temperature of 21°C. Such deterioration becomes particularly noticeable when the cabin temperature rises to 27°C or higher.

All this leads to an increase in probability of greater or lesser decline of vigilance and, in some cases, even falling asleep on the job. The periods of loss of vigilance during a long run are most often in the form of sudden "blank" periods. But no matter how brief these "blanks," they harbor a great danger if there is an emergency situation at such a moment.

Even the fact that the engineer is in the most dangerous place in case of a wreck does not prevent him from such "blanks." Records of accidents that occurred at the fault of engineers confirm this assumption. According to the data of the staff of the Sverdlov All-Union Scientific Research Institute of Labor Safety, who analyzed serious accidents on the railroad, which occurred at the fault of engineers in 1970, found that about 50% of the incidents are attributable to loss of vigilance.

This enables us to single out the capacity to maintain a state of readiness for emergency action in response to a signal, the time of which is not defined as a condition, as a significantly determining factor in accident-free work of an engineer.

Attention is a most important psychological factor in successful performance of engineer work. Among the general properties of attention, those that are of professional relevance to engineer work are distribution, intensity, as well as stability, i.e., the capacity to maintain the necessary level of attention for a long time and, at the same time, without concentrating it for a long time on only one or several objects, but to have the entire situation in his "field of vision."

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One of the factors that is involved in diminishing this important function is, as we have already mentioned, monotony which is a condition inherent in train-running work.

The work of a mainline locomotive engineer proceeds against the background of constant and significant nervous-emotional tension, due to awareness of his enormous responsibility for the life of passengers and pedestrians, property, running through restrictive signals and staying on schedule.

As we have already mentioned, the engineer performs relatively few actions and they are not complex in structure. But each action is extremely important, since any error in his work could lead to the most serious consequences. It is expressly this responsibility for each of his actions that causes the emotional tension, the emotional background against which all of his work to run the locomotive is performed.

In addition to this constant "moderate" emotional background, in the course of train-running work there are sometimes incidents that evoke acute emotional stress. Examples of such instances are the unexpected appearance of a pedestrian crossing the track, a vehicle stuck at a crossing, sudden malfunction, etc. And the greater the probability of such instances, which present a threat to safety of movement, the more intense and tiring is the run.

Psychological tensions affecting the engineer are constantly increasing in view of the ever increasing speed of travel. This leads to ever increasing difficulties in man's adjustment to professional activity. As the difficulty of adjustment increases, so does the intensity of the stress situations, which create an additional emotional burden and impose certain demands of the general emotional and volitional personality traits, rather than individual qualities or isolated functions of man. Consequently, successful performance of engineer work is largely determined by his emotional and volitional stability in critical situations, as an important professional quality.

The importance of the above-mentioned functions and skills becomes increasingly acute with increase in speed of travel, as a mandatory prerequisite for successful work when time is short.

In spite of the fact that there is no change in manipulations of the engineer to perform various train-running operations at high speed, the increase in speed causes rapid change in the situation. When traveling at high speed, there are considerably more stimuli for the engineer per unit time.

Under such conditions, the engineer has to discern different road situations and readings of instruments on the console faster, and there is considerably less time at his disposal to perform some emergency action related to the process of controlling the locomotive.

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It has been determined that attention worsens when traveling for a long time at high speed, due to the rapid succession of different objects along the roadside and stimuli that are observed in the form of a continuous solid series. Thus, for example, the time spent by engineers to switch attention (Schulte-Platonov table) increased substantially after 6 h of train-running work (from 21 s to 1 min and 23 s), whereas after 3-h work, the difference in time was insignificant (17 to 23 s).

Analogous data were also obtained with respect to number of mistakes made.

When there is a heavy work load, the question inevitably arises as to the possibility of controlling the locomotive with sufficient reliability. Interestingly enough, engineers display much interest in their work, they are aware of its difficulties, importance of professional training, and they very often spend their leisure time to advance theoretical knowledge, to study the diagrams [systems] of different parts and units.

As a rule, there are no individuals who selected the specialty of railroad engineer by chance. Analysis of questionnaires revealed that 80% of the locomotive crews began their career on the railroad. It was also shown that railroad engineers chose this occupation essentially on the basis of leaning, interest, family tradition, and they are guided by effective, vital motives.

Of the many engineers and assistant engineers questioned, only 6.5% expressed dissatisfaction with their work. Individual interrogation revealed that such answers refer chiefly to dissatisfaction with organization and conditions of work at a station, rather than the occupation as a whole.

In the professional activity of an engineer, an equally important factor is that his work is related to a constant change in surroundings, abnormal mealtime schedule, periodic absence from home, not only on week days, but on holidays. All these circumstances should not be considered simply as additional difficulties, over and above the main background of work. In many respects, they create the unique specifics of the work of a railroad engineer, which distinguish this occupation from all others.

Such are in general features the psychological characteristics of the occupation of mainline locomotive engineer.

In summary, it should be stated that the most important and professionally significant mental traits required for successful performance to control a locomotive, assuring the safe movement of trains, are as follows: capacity for large sensory loads; resistance to monotony, ability to constantly predict the road situation; readiness for emergency action; concentrated, intense and stable attention; emotional stability; high motivation.

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CHAPTER 3. ENGINEERING PSYCHOLOGICAL FACTORS OF RELIABILITY OF RAILROAD ENGINEER WORK

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[First section of Chapter 3 from the book "Inzhenernaya psikhologiya i problema nadezhnosti mashinista" by L. S. Nersesyan and O. A. Konopkin, Izdatel'stvo Transport, 5100 copies, 240 pages]

[Text] Optimization of Work Environment From the Aspect of Engineering Psychology

The specifics of the work of an operator-engineer impose their own special requirements of engineering psychological aspects of the work place in the cabin of a mainline locomotive. Active work is being pursued to develop universal locomotive cabins in the USSR, Canada, FRG and the United States. American scientists have studied this problem as applied to urban railroads with different levels of automation of train running.

However, in spite of several original designs for optimization of the work place in a locomotive cabin, the number of such projects is very inadequate. As an example, we can mention the patent search made by V. F. Tkachenko and Yu. L. Kogan, who work in the sector of scientific and technical information of the Central Scientific Research Institute of Railroad Transportation, in order to systematize Soviet and foreign inventions of recent years pertaining to the engineer's cab. Their data are listed in Table 1.

As can be seen in this table, the inventions pertain mainly to different elements of design of the cab, such as the air-conditioning system, seat, control console with three-dimensional panels, etc. True, we do encounter in scientific publications some good engineering psychological designs for some elements related to locomotive control. As for the complex solution to problems of increasing reliability of engineer work by means of optimization, from the standpoint of engineering psychology, of the design of equipment in the work area of the locomotive cabin as a whole, thorough enough work in this direction has not been performed.

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Table 2.

Patent or author certificate No	Country	MKI classification	National class index	Patent annotation
345034	USSR	V61 17/10	--	Floor board with panel of soundproof material
364487	USSR	V61 17/04	--	Suspension of removable cab equipped with resilient elements to reduce noise and vibration
357110	USSR	V61 33/00	--	Engineer's seat with device to attenuate vibration, with additional adjustment to his weight
3779175	United States	V61 17/04	105-456	Storm frame to protect engineer when looking over train in bad weather
3791313	United States	V61 49/00	105-456	Adjustable wind deflector with rear view mirror
420490	USSR	V61 33/00	--	Engineer's seat with anti-vibration device in the form of a spring
399405	USSR	60k 37/00	--	Control console with three-dimensional panels
3848428	United States	n25 v21/14	62-285	Air-conditioning system in engineer's cab
3855450	United States	n05 v1/02	219-367	Cab window heater with device to deliver air to electric heaters also

With the increase in speed of train movement, when the external flow of information increases and time to process it is decreasing, the efficiency of operator performance to control the system depends more and more on how efficiently (rapidly, accurately, completely) he receives information from the system's display devices.

The total number of visual display devices that an engineer uses is quite large, while accurate reading thereof is mandatory to perform the correct actions for control. For this reason, the engineer must be able to perceive the necessary information from the instruments as rapidly and accurately as possible. This is a rather categorical requirement for the work of an engineer.

As in many other technical systems, there are two types of indicators on the consoles of modern mainline locomotives: those with dials used to

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relay information about the quantitative parameters of the controlled process and directions of changes therein, and control indicators, to relay information about qualitative changes in the controlled system. It is expedient to discuss each type of indicator in greater detail.

Indicators with dials: There are relatively few (6-15) indicators with scales in the engineer's cabin; the number varies, depending on the type of locomotive. Most often instruments with pointers are used for such indicators.

On locomotives manufactured in the Soviet Union, the dial type indicators usually have a round or semicircular stationary dial and movable pointer; on foreign ones, particularly series K and ChS2 electric locomotives, wide use is made of indicators with a vertical, stationary dial and horizontal movable pointer (for instruments pertaining to power mode).

In order to assess the comparative effectiveness of dials differing in shape, one has to consider the results of a number of studies in engineering psychology. As shown by these studies, instruments with a stationary round dial are more effective than with a vertical stationary dial, since the former are referable to the two-dimensional category of stimuli, while the latter are referable to the category of one-dimensional stimuli. In addition, the trajectory is shorter for the eyes when reading a round dial.

On the other hand, it is known that when time is extremely short the instruments with movable dial and stationary pointer have the advantage since it takes less time for visual location of the pointer. For this reason, we believe that it is desirable to use horizontal, movable dials situated one under the other, with stationary vertical pointers, for electrical measuring instruments that are indicators used constantly. This assures adequate accuracy of taking readings when time is short, and it reduces the perception zone when laying out the instruments.

The lay-out of information panels on control consoles with the use of instruments only with round dials is not good in most cases. The panel is then extended, and this augments drastically the total trajectory of the eyes to take readings.

At the same time, it is preferable to use round dials for instruments whose readings must be taken with specified [regulated] accuracy. This applies, first of all, to pressure gages. It permits compact grouping thereof on the control console on the basis of common functional feature, as well as to increase accuracy of taking readings. Evidently, use of dials of different types for instruments serving different purposes should be made by grouping them according to function, and this would facilitate retrieval of needed information.

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But it must be stressed that the optimum implementation of this suggestion is related to organization of an experimental verification, particularly to rate the effectiveness of taking readings from groups of such instruments that are arranged in a specific way on the information panel.

In our opinion, the obviously large size of dials in use is among their substantial flaws. Studies in engineering psychology do not confirm the opinion still held among engineers that the speed and accuracy of instrument reading increase with increase in instrument size. The correlation between diameter of a scale and reading accuracy is not linear.

V. Greter and A. Williams [Vil'yams], who studied readability of round dials 25 to 100 mm in diameter from a distance of 750 mm, found that accuracy of reading first increases with increase in diameter, then decreases. The experiments of A. A. Krylov, who used dials of the same shape but with different diameters, revealed that reading accuracy and speed diminish when the diameter of an instrument exceeds 50 mm. According to other data, a diameter of 75 mm should be considered optimal.

Evidently, when selecting the size of a dial one should bear in mind the significance of the readings of a given instrument. Instruments reflecting the most important information should have dials with larger diameters and those referable to less important information, dials with smaller ones (within the optimum range).

The design of instrument dials produced by industry and installed on locomotives does not always conform with the specifics of engineer work. Among the common flaws are the absence of a standard system of their color, scale factor, rendition of digits, etc.

In a number of instances, dials are used whose readings are too precise, when this is not necessary. We refer to the presence of too many lines which are virtually indiscernable under actual train-running conditions.

Easier interpolation of pointer readings in the intervals between distinct large divisions could be a more effective means of improving reading accuracy.

We must also mention the use of an additional measure for better identification of instrument readings. We refer, first of all, to color coding of different parts of the dial corresponding to different operating modes. It is virtually not used in modern locomotives, although it would be very simple to do. There is only a small number of instruments where maximum values of some parameters are shown.

These maximum values are indicated by a red line; yet one should consider solid painting of different segments of the dial in a color code more effective.

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Apparently, one should recommend the use of "prompters," i.e., special signals (audio or color) that are triggered if there is a disruption of system operating mode.

In analyzing questions related to optimization of instrument reading, we should discuss the possibility of using skills already developed in each person for reading the most common types of dials, such as, for example, a clock dial. For this purpose, we proposed and experimentally tested the comparative efficacy of pressure gages with clock dials having 10 divisions and a nonfunctional segment from 10 to 12 delineating the beginning and end of the dial.

At the same time, use on locomotives of a clock dial with 24 graduations integrated with the dial of the speed indicator is apparently unjustified. This would create the possibility of adverse influence of the habit of reading the ordinary clock dial formed and constantly reinforced in everyday life. This is undesirable, in view of the importance and frequency of referring to the time in the course of an engineer's work. Use of a dial with 24 divisions also adds some difficulties to the learning process.

The measures referable to organization of the operator's work place include provision of optimum conditions for visual activity, which is characterized not only by the visible tracking distance and convenience of viewing, but level of distinct visibility of instrument readings. In this regard, the zones of visibility of display devices, as well as rational placement of instruments with dials that are used both periodically and constantly within the limited working space on the operator's console are of prime importance. For example, it was established that the speed of taking instrument readings, when they are situated in different quadrants of the instrument panel, differs. Experimental studies of the zones of predominant concentration of the operator's eyes on the instrument panel revealed that there is more effective perception of signals in the left upper part of the field, other conditions being equal. This was reliably established in experiments with railroad engineers.

According to the data of White, the frequency of fixing the eyes on different parts of the panel with equal significance of all instruments is distributed as follows: top left corner 46%, top right corner 29%, lower left corner 11% and lower right corner 14%. This indicates that the most frequently used and most important instruments should be placed in the left upper corner of the instrument panel on the control console.

Quite often, when instruments are laid out on the control console, designers disregard psychophysiological factors, which is manifested, in particular, by unwarranted increase in overall dimensions of the

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perception field and absence of clearcut principles regarding the relative location of different instruments or groups thereof within this field.

Indicator devices for reference readings: In addition to displays for quantitative readings, there are 4 to 16 reference displays in the cabin of a locomotive engineer. They give the engineer information about operation of the controlled system and occurrence of emergency situations.

Of course, to read reference displays one must properly identify the meaning of the signal. This is usually achieved by increasing the number of distinctive features inherent in this signal. Unquestionably, color should be considered the most effective of these features, but this is not always taken into consideration by designers. Wide use of inscriptions for the indicators does not help interpret the readings, since the inscriptions are not usually distinct enough. The absence of a standardized system for arrangement of reference indicators makes it even more difficult to take readings from them.

There is an objection to the diversity of placement of reference displays (for example, on different series of electric locomotives), so that when an engineer changes to a different locomotive he has to make a readjustment each time, and this prompts justified criticism on the part of locomotive crews.

Since the sudden lighting up or change in color of a qualitative display is noticed rather well, such displays can be placed on the periphery of the instrument panel field. At the same time, if these displays are too far from the central field of vision of the engineer, they may be more difficult to read and to promptly detect an important signal.

The presence of a display brightness regulator is also of substantial importance. The use on some locomotives of brightness regulators enables the engineer to set the display brightness level that does not produce excessively sharp color contrast between the signal and general background, but is adequate for perception. At the same time, the absence of such regulators on locomotives makes it necessary to constantly readjust eye function (visual readaptation), which has an adverse effect on the visual analyzer and could serve as the cause of its rapid fatigue.

These comments also apply to the brightness of ALSN [automatic cab signaling ... ?] signals. The fact that engineers often resort to the use of a paper patch to cover the signal field, particularly at night, is proof of the importance of this circumstance.

It is also difficult to perceive displays of this type because they are set too deeply in relation to the console surface. For example, on some locomotives they are set in to a depth equaling the diameter of the display itself, and engineers seated in the usual position often do not see the signal at all.

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Operating controls: Psychological rationalization of the design of the system for delivering signals to man on modern types of locomotives is only one of the problems of human engineering, the problem of conformity of the sensory "input" of man with the informational "outputs" of machines. An equally important matter is optimum organization of locomotive operating controls, placement thereof in the most convenient zone and at convenient distances, choice of optimum variant of direction of movement of levers and handles, determination of the force required to use them. For this reason, in this chapter we concentrate chiefly on the design and arrangement of controls required to implement decisions made by the operator.

On locomotives, the controls may be of different types: control handles, switches (including tumblers), buttons, pedals, steering wheels.

The handles [or knobs] installed on locomotives can be divided into two groups: those used constantly--main controller handle and engineer's valve [brake?]; those used periodically or once, reverser handle, safety ["ancillary] brake, sander, handle to disconnect the main brake system, handle to secure position of hand brakes, etc. (Figure 4).

The correct (uniform) distribution of control functions between both hands of the mainline locomotive engineer is an important engineering psychological problem in the design of the work place.

Studies conducted by the Georgian branch of the All-Union Scientific Research Institute of Aesthetic Styling in Engineering established the burden on the engineer related to manipulation of operating controls. The results are listed in Table 2.

This table shows that there is nonuniform distribution of control functions between the two hands. The left hand, while operating the controller, remains in one position longer than the right hand (with the main handle alone, 44 operations are performed lasting a total of 210 s). The right hand, which operates over a wider zone, operates a larger number of controls with an overall load that is 2.5 times longer in time than for the left hand.

Thorough time studies of distribution of the work time of diesel and electric locomotive engineers between different work operations on flat sections of road and over the Carpathian pass enabled the staff of the laboratory of industrial psychology, physiology and hygiene of the L'vov Railroad to determine the number of manipulations performed with operating controls and mean time spent on different operations. The results of this analysis revealed that, regardless of road conditions, there is an analogous irregularity in the work load of each hand.

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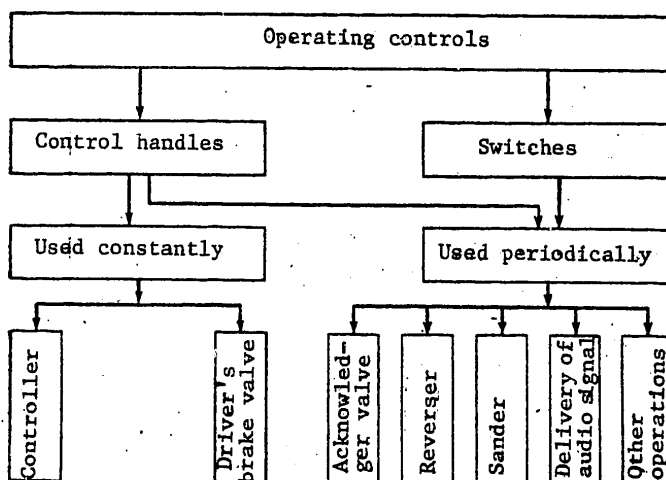


Figure 4. Classification of locomotive operating controls

Table 2.

Name of control	Right hand			Left hand		
	Frequency of use	Time, s	%	Frequency of use	Time, s	%
Main handle (controller)	--	--	--	44	210	42
Field attenuation handle	--	--	--	32	253	50
Reverser handle	--	--	--	7	23	5
Horn	26	114	8	--	--	--
Sander	18	684	49	--	--	--
Acknowledger handle	14	384	27	--	--	--
Valve No 222	10	89	7	--	--	--
Valve No 254	8	82	6	--	--	--
Checking device switches	--	--	--	7	15	3
Radio	2	43	3	--	--	--
totals	78	1396	100	90	501	100

For this reason, it is expedient to execute some of the controls, i.e., whistle, sander, headlight switches, in the form of pedals, so that the engineer could operate them with his feet.

In many electric locomotives, the main controller lever is located on the left and the brake valve on the right. This is ergonomically justified,

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since the left hand is more accurate in movement and capacity to graduate force, which is important to operate the controller, while the right is stronger and moves faster, which conforms with the requirement of emergency braking. In addition, movement of the main controller level forward corresponds to gaining speed and backward, to reducing speed. This creates a logical conformity between the direction of movement of the control and the controlled object.

An original design was created for the controls on ChS4 and ChS2T locomotives. In these series of locomotives, the positions of the controller are changed by means of a half-wheel or wheel 400 mm in diameter, which is located in the center of the work place.

This location makes it possible to release the left or right hand alternately, concurrently with group switching to a different position, to perform the necessary operations with other controls.

It must be stated that both of the above-mentioned lay-out principles may be considered equally good and justified from the ergonomic point of view.

The arrangements are not as good on the TE3 diesel locomotive, where not only the controller, but the brake valve are to the left of the engineer. This leads to inconvenience during routine train-running work, and it is not acceptable from the standpoint of traffic safety, since the engineer has to make two successive movements with his left hand for emergency braking: first change the position of the controller and only then, with the same hand, turn the brake valve.

We consider it rational to provide a special sealed lever on the locomotive control console, a type of stop valve, the operation of which automatically performs all the necessary steps for emergency braking (turning controller off, dropping pantograph, releasing sand and emergency braking) in the required order. This device should be located on the console of the engineer and his assistant, and it should be independent of locomotive operating controls.

The so-called reaching range is a most important feature of the work place in a locomotive cab. At the same time, human anthropometric data are not always taken into consideration in laying out controls that are used constantly.

The optimum range of angles of rotation of levers from 30 to 60° is not provided on many locomotives. Not infrequently, the brake valve has to be turned over 140-180° to apply the brakes. And both during initial turning of the handle over 20-30° and particularly at the end of the braking operation over the last 20-30° of rotation of the brake handle, hand movements that are uncomfortable and biomechanically unrational have to be performed with the mandatory involvement of several articulations:

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radiocarpal, ulnar and brachial, with concurrent elevation of the elbow and arm (introversion of the hand). The same occurs when using the main controller handle.

It should be noted that optimization of location of working zones for controls should also be implemented by means of correct location of the engineer's seat. This is particularly effective in cases where the dimensions of controls are the same in different locomotive cabs. One should consider the use of a seat on an unfixed, stable broad base, that moves freely over the cab floor, to be the best variant.

The different arrangements of main control levers in modern locomotives indicate that designers are not quite sure which arrangement of levers should be considered optimal. For this reason, one of the next tasks for engineering psychology is to organize experimental research to provide a definitive solution to the problem of optimization of controls from the standpoint of working man.

Diverse switches make up the largest group of controls. Their number ranges from 5 to 23 for engineers and 0 to 12 for assistant engineers, depending on the type of locomotive.

One should consider the use of switches justified and rational in cases where control is limited to two states: "on"--"off" with retention of the setting over a long period of time. Switches usually turn the following locomotive systems "on" and "off": inside lights (cab, measuring instruments); outside lights (headlights, underframe); cab and windshield heater; ventilation; radio; control of pantograph, etc.

However, in some locomotives, for example, VL60, VL80, switches are also used to release sand and for audio signals, which cannot be deemed sufficiently warranted. It would be more desirable to use buttons or pedals for these purposes, like on other locomotives. In addition, it would be then possible to distinguish the horn and whistle from several other identical switches used only once.

The arrangement of switches should conform with the following requirements of engineering psychology: good visual distinction between "on" and "off" positions; presence of the "click effect" when used; ease of handling, minimal micromovements, possibility of movement with any finger; counter-sunk installation, particularly for tumbler type switches to prevent accidental tripping.

We must also mention the inadequate application of the principle of grouping switches together according to function, which extends significantly the time of sensory search to choose the required control and could lead to errors. There is every justification for moving a number of one-time use switches away from the control console. This would not only significantly disencumber the console, but permit more purposeful arrangement of the switches that are left on it.

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The following can be used for functional grouping of instruments: distinction of functional groups by color, relative position; use of switches of different forms. However, this is not done on most locomotives.

Use of mnemonics on locomotives is very desirable to accelerate visual retrieval of the required control

On modern locomotives, particularly diesel ones, there is a rather large number of buttons. Buttons may also be classified as controls (of the type of acknowledger handles), where simple depression is the work movement. Buttons are used widely for audio signals and release of sand. As a rule, they are small in diameter (12-20 mm), but occasionally up to 60-70 mm. Such enlargement of button diameter increases significantly convenience of using them (search, speed and accuracy of motor action).

The way buttons are arranged in the work place is not always sufficiently justified. For example, on Soviet locomotives, horn, whistle and sander buttons are generally on the right side of the cab wall. When the armrest is lifted, it is very difficult to use them.

Occasionally, the buttons for signals and release of sand are backed up by pedals. Aside from convenience under ordinary working conditions, this reduces drastically the time required for emergency braking (due to distribution of the required action over all four limbs of the engineer).

Wheels are used mainly for hand brakes (in addition to the cases described above where a wheel is used as a controller), and they are equipped with a tapered handle that is rather long (120-130 mm). A close to optimum wheel diameter (350-500 mm) has been chosen.

It should be noted that radio equipment is often inconveniently located, particularly when in the work place of the engineer, rather than his assistant.

Thus, analysis of control consoles in the cabs of mainline locomotives referable to some domestic and foreign models revealed that none fully conforms with the requirements of engineering psychology. At the same time, each series has its own, sometimes original and interesting features; an optimum combination thereof in one model would permit considerably better organization of the engineer's work process.

The differences in arrangement of the main control levers in different types of modern locomotives indicate that designers do not have a clearcut idea about which arrangement of levers should be considered optimal. In the practice of locomotive building, control consoles are usually designed on the basis of "common sense." Of course, such an approach not uncommonly leads to serious mistakes. Yet, even now, some concrete recommendations and requirements have already been developed

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by engineering psychology and ergonomics, with reference to the operator's work place, and they provide a certain foundation for practical solutions of these problems.

Several of the questions that arose as a result of this analysis made it necessary to organize experimental research. We submit below a description thereof and the results obtained.

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CHAPTER 5. INVESTIGATION OF PSYCHOLOGICAL FACTORS OF RELIABILITY

Moscow INZHENERNAYA PSIKHOLOGIYA I PROBLEMA NADEZHNOTI MASHINISTA in Russian 1978 signed to press 25 Aug 78 pp 139-197

[Chapter 5 from the book "Inzhenernaya psikhologiya i problema nadezhnosti mashinista," by L. S. Nersesyan and O. A. Konopkin, Izdatel'stvo Transport, 5100 copies, 240 pages]

[Text] Determination of Professional Fitness of Engineers

The problem of determining the professional fitness of engineers is one of the focal ones for safe travel on the railroad. We refer to both screening of secondary school graduates for railroad engineer schools and periodic recertification of professional engineers. The set of issues that is raised in this regard has not yet been definitively resolved. It is particularly difficult to assess the prognostic value of methods, and the principles of implementation thereof may vary.

Our survey of operator-engineers was conducted for two immediate purposes. In the first place, we developed and rated specific new methods that are suitable for determination of professional reliability of engineers. In the second place, we compared two different approaches to determination of professional reliability of engineers.

The first approach could be referred to as "differential psychophysiological." It is based on the thesis that individual typological properties of the central nervous system are the significant factor in efficiency of the work of an engineer.

The second approach is based on the fact that goal-oriented voluntary activity of man is largely independent of typological properties of an individual's nervous system. Of course, this refers to the results of the work, and not to the style of performance thereof, let alone the purely external dynamic characteristics of work actions.

Each of these approaches required different methodological directions of research: the first involves the use of traditional differential psychophysiological methods of determining the main properties of the nervous system and the second, modeling of the psychological structure of performance as a whole.

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As we undertook our work, we did not consider the above approaches to be mutually exclusive. We set one of these approaches against the other chiefly for methodological considerations. We did this, in the first place, as applied to one specific occupation and, in the second place, confined it to specific methodological variants of implementing these approaches.

As related to specific occupations, such a comparison of relative efficacy of identifying properties of the nervous system and psychological modeling of performance is, in our opinion, practically rational and theoretically interesting. Why did we use these two approaches? Perhaps, preference could be given to one of them on the basis of already existing data?

The scientific and applied significance of the problem of "typological properties of higher nervous activity (HNA)--industrial activity of man" does not require any special justification. The practice of occupational screening is precisely one of the most distinct instances of specific applied importance of this problem. However, there are rather significant and multi-aspect difficulties in studying the typological determination of voluntary forms of human behavior. As a result, the typological aspects of occupational fitness, as one of the specific variants of the problem in question, have not been analyzed in sufficient detail. They are still quite far from a degree of development that would permit confident use thereof in occupational screening.

While it is easy to concur with the general hypothesis that individual expression and uniqueness of individual combinations of properties of the nervous system cannot fail to affect many of the distinctions of an individual's psychological make-up, his behavior as a whole, the more concrete patterns of this relationship are still not clear enough. On the other hand, it is also certain that typological distinctions of HNA are not significant, let alone prime factors of achieving success in an entire series of activities.

In general form, this thesis was best formulated in the well-known statement of B. M. Teplov: "Whatever the type of his nervous system, man can attain high individual achievements."

There are diverse scientific facts indicative of the validity and justification of this statement. Some of them pertain to the consistent innate relations between properties of the nervous system, which compel us to be very cautious in defining a vital value, the degree of manifestation of different properties of the nervous system.

An example of this is the demonstration by V. D. Nebylitsyn of inverse relations between strength of the nervous system and its inherent level of excitability.

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V. I. Rozhdestvenskaya and others have discovered a fact that is similar in meaning, that of greater endurance of people with a weak nervous system for relatively simple, but monotonous work.

Determination of occupational fitness requires as full information as possible about such correlations between characteristics of the nervous system. Without this, formulation of contraindications for some occupations may be unfounded. Perhaps, these patterns are merely individual instances of an entire class of such phenomena, when relative "trouble" with one of the HNA characteristics is consistently combined with accentuation of some vitally important characteristic.

Another group refers to facts indicating that successful achievement of complex forms of voluntary human activity may be largely independent of the properties of the nervous system in cases where the individual finds a style of work and behavior that is consistent with the individual distinctions of his psychophysiological organization and the work to be performed, and masters this style.

The monograph by Ye. A. Klimov, which deals with the question of individual style of performance, gives a systematic summary of the research done in this direction.

In spite of the fact that the existing studies of this problem disclose some facts that are quite essential to its solution, at the present time the industrial psychologist often finds himself in a rather difficult position, when he has to answer the question: Is screening that takes into consideration the individual set of nervous system properties in candidates necessary for a given, specific occupation? This is not surprising. This question actually covers a multitude of others, which have not yet been worked on sufficiently. Which are the professionally important mental phenomena of the personality, in what forms of actions, on what levels of complexity of performance, with what degree of novelty, uniqueness and unexpectedness of working conditions, with what degree of responsibility of work, etc., can the properties of the nervous system play the role of an essential factor?

Prediction of professional achievement is also more difficult because, in some cases, substantially different efforts made by different individuals may be involved in relatively equal results of labor. The specifics of work may conform to varying degrees with the natural leanings of an individual, which are related to his individual distinctions, as is indicated in the monograph by K. M. Gurevich, who deals with questions of professional fitness. This author calls attention to the fact that extremely nervous work, related to forcible self-subordination in the course of performance of work, results in the worker's constant overcoming of a distinctive internal conflict. As a rule, an individual cannot gain satisfaction from the process of his work, and he often changes occupations. Of course, one cannot fail to take into consideration

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the nature and degree of motivation in professional activity, which also influences the attitude toward work.

The same monograph formulates the thesis that there are two types of occupations and, accordingly, two types of occupational fitness.

In the first type of occupations, performance is related to high and rigid requirements with regard to speed (pace) of performance, situational changes in significance of different signals, need to switch rapidly from urgent actions to active containment of actions and, vice versa, occurrence of new, unforeseen situations involving much personal responsibility.

These and similar facts, considered separately and in different combinations, relate the formation of fitness of this type of profession to some innate features of the individual.

The second type refers to occupations, formation of fitness for which is unrelated to the existence of very specific individual psychological elements.

It is difficult not to agree with the fact that there are occupations requiring specific typological nervous system properties, as well as those, for which consideration of innate features of the nervous system has virtually no meaning.

However, the factors characterizing occupations of the first type are quite diverse, and there is even greater diversity in combinations thereof and extent of manifestation in specific occupations. It is expressly in this regard that the occupation of railroad engineer is very interesting. On the one hand, this is a rather widespread occupation that tens of thousands of people can handle; on the other hand, there is manifestation of factors in it, overcoming which would appear to require a specific typological set of nervous system properties. The high personal responsibility, possibility of unforeseen situations and need for urgent action require emotional stability of the engineer, even in the case of an ordinary run, as well as prolonged maintenance of a high level of alertness, capacity to rapidly assess a situation and switch immediately from operational rest to external activity.

As applied to the work of an engineer, a priori assertions that the typological aspect of occupational fitness is necessary or unnecessary would not be sufficiently justified, while relegation of this profession to the first or second type requires special "typological rating." For expressly this reason the first approach in our experimental work consisted of assessing some of the typological distinctions of the nervous system of engineers as a factor capable of determining the degree of success of their professional performance.

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The second approach, as we have already stated above, is an alternative to the first one, and it was based on the hypothesis of broad and diverse compensatory capabilities implemented by man in the course of his occupational activity.

This direction of research can be followed only with integral modeling of the work studied. We chose the route of functional systemic analysis of voluntary regulation of activity directed toward isolating the functional elements of the self-regulation system related to the main difficulties involved in the work of an engineer.

Functional systems analysis of engineer work was preceded by professional analysis thereof, the purpose of which was to identify the main psychophysiological features causing specific difficulties in the work of an engineer. We singled out the following in the capacity of such features:

1. General monotony of work, related to perception of many similar signals and objects along the train route.
2. High share of visual information and consequent leading role of visual perception in detection and identification of meaningful signals.
3. Objective need for continuous and intensive attention, which is related not only to the tasks of accurate perception of track signals and signs, but the constant possibility of sudden extraordinary situations requiring control action of maximum speed.
4. The leading role of information from signals and events occurring outside the controlled system proper. This is attributable to the fact that perception of instrument information and controlling manipulations are performed by standard, highly automated procedures are periodic and occur, so to speak, against the background of continuous and intensive external observation. It is expressly the results of external observation that determine the frequency, specific time, direction and meaning of action related both to obtaining instrument information and inputting command information in the system.
5. High degree of spatial and dynamic coordination of different series of controlling action. Such series must be performed not only rapidly enough, but with strict adherence to a rational sequence of different elements. Intensive "external" observation makes it difficult for the engineer to practice thorough visual checking of the motor aspect of performance which, for this reason, is significantly controlled by information delivered through the channels of the motor analyzer.

With reference to the factors isolated in the aspect of psychological self-regulation of activity, we can see that most difficulties in the profession of railroad engineer are directly or indirectly determined by

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the specific conditions of formation and function of an element of self-regulation such as the subjective model of conditions of activity.

For a number of operator occupations, where decision making is limited to clearcut and rather simple algorithms, while ongoing feedback about control action is well-provided, the main difficulties of regulation of work are related to accurate and prompt reflection of working conditions, i.e., formation of the subjective model of these conditions.

Indeed, for the operator, the subjective model of working [activity] conditions is the source of information for decision making; the nature of the programs that the operator runs to control the system depends on the completeness of this model and conformity with objective conditions.

When designing methods to simulate the process of running a locomotive, we took into consideration, first of all, the conditions under which the operator-engineer constructs and corrects the subject model of conditions of his activity. Of course, we realized that experimental performance cannot be an ideal model of the professional performance of an engineer, and it must take into consideration the most important psychological factors. It is also understandable that the prognostic effectiveness of such a method is by no means related to copying the external operational aspects of running a train.

Being psychological in orientation, our method did not reflect a number of loads inherent in the work of an engineer, for example, static muscular load related to a specific body position, loads occurring as a result of the influence of cab microclimate, loads occurring in a number of cases as the result of prolonged work, noise and vibration, specific work and rest schedule, etc. In addition, we wanted the experimental procedure to be feasible with rather simple equipment. We believed that such a method should simulate the main psychological structure of engineer performance and address itself to the combination of mental functions and processes involved in performing actual train-running work.

Evaluation of strength and lability of the nervous system: We used a parameter developed by V. D. Nebylitsyn to assess the relative strength of the nervous system of locomotive engineers. This parameter is based on the hypothesis expounded by B. M. Teplov of a regular correlation between absolute sensitivity and strength of the nervous system. Manifestation of the "law of strength" in reactions to signals of different intensities is such a parameter. Its meaning is determined by the fact that subjects with a stronger nervous system show a consistent decrease in latency time of reactions to a wide range of stimuli of moderate and strong intensity. As for individuals with a relatively weak nervous system, they reach the maximum acceleration of reactions sooner, i.e., with stimuli of lower intensity.

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In turn, we used two forms of assessments in statistical analysis of the data. In the first, we calculated the coefficient of linear regression b , which gives us the integral characteristic of the slope of the curve of reduction of reaction time as a function of increase in intensity of stimuli. The second evaluation was obtained as a result of the percentile relationship between reaction time to the weakest and strongest signal. Unlike coefficient b , this rating is more convenient for high-speed processing. Since there is evidence that the properties of the nervous system that are tested by traditional methods are "partial," i.e., demonstrate mainly the distinctions of the regions of the brain to which the stimulus is directed, we used two variants of this method.

We used the "visual" variant as corresponding directly to the nature of the information load on the engineer. The burden on the auditory analyzer is much smaller in the work of an engineer, so that the second variant of the method was used as a sort of additional check of the overall evaluation of occupational meaningfulness of the strength of the nervous system according to the excitatory process.

Experiments dealing with reaction time were conducted according to the usual scheme for tests of sensorimotor reactions, where the subject reacts to signals by depressing a key, stopping a stopwatch that is started at the same time as delivery of the signal stimulus. We used stimuli of four intensities, each of which was presented 10 times in the test. Signals of different intensities were presented in random order.

We used the critical flicker fusion frequency (CFFF) as the parameter of lability of the nervous system.

Experiment reflecting the distinctions of self-regulation of engineer work: As indicated above, experimental activity should be addressed to a combination of the same mental functions as occupational activity, while regulation thereof is performed under conditions that are comparable to real working conditions for an engineer.

A high "monotonous" burden on the visual analyzer was created in the experiment by means of continuous presentation of series of black and red digits to the subject. The digits were displayed in a special slot on a vertical panel situated at eye level at a distance of 55-60 cm from the subject.

The subject had to call aloud each of the odd numbers rendered in black. Since such numbers were displayed at random, the subject had to watch the slot continuously. The speed of presentation of digital signals constituted five symbols per 2 s.

Against the background of a continuous flow of digital signals, 20 command signals were presented to the subject over a period of 50 min at irregular

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intervals. Their source was a special light indicator situated in the immediate vicinity of the slot. Presentation of these signals in the course of the experiment required the immediate performance of predetermined sets of control actions by the subject. A flash of green light required a set of actions arbitrarily designated as "starting" the locomotive. A red flash was related to the controls for "braking."

To perform such actions, the subject had a console with six buttons and a brake valve. The function of each button was identified by symbolic signs above them: "whistle," "sand," "engine," "pantograph," "compressor," "horn."

The subject had to perform a controlling action as rapidly and accurately as he could that conformed with the command signals and, at the same time, perform as accurately as he could the task pertaining to calling out the black odd numbers. The following served as criteria of subject performance: 1) time of identification of command signals (from delivery of signal to depression of the first button); 2) accuracy of identification of command signals and proper control action (conformity of the control complex with the delivered signal, elimination of some control actions from the complex, disruption of their order, etc.); 3) total time of controlling action (from delivery of signal to completion of the entire set of control operations); 4) number of omissions in monitoring the digital signals.

The parameters obtained in the course of the experiment (latency period, total time, errors, omissions) were recorded not only separately, but as an integral rating of experimental performance of each subject.

Such a rating, which integrated special parameters, covered both the time and accuracy aspects of the subjects' performance.

Since an increase in absolute value of each of the experimental parameters signified poorer performance under our conditions, when performance improved the absolute values of the parameters dropped, we expressed the overall rating of performance as the simple sum of the different parameters.*

In all cases, the main experiments were preceded by training tests, in the course of which the subjects learned the instructions well and acquired the necessary skill in working on the experimental console. We used this method to test engineers with work tenure of 5 to 25 years at the Zaslauks (45 people) and Kiev-Passazhirskiy (40) stations.

*We combined the special parameters referable to speed and accuracy of performance by the subjects in a single integral rating in a preliminary test. The purpose of this test was to obtain some data concerning the possibility and wisdom of using such an indicator. The final method of obtaining the overall indicator requires special refinements.

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The data referable to these groups were analyzed separately in order to determine the possible influence of some conditions inherent in the professional activity of engineers working on different lines, with different road profiles, climate, different train-running speeds, etc., on evaluation of the method.

Evaluation of professional achievement: It is imperative to establish unequivocal conformity of the results of a psychological examination and actual professional achievement of subjects in order to determine whether a given psychological method is suitable for occupational screening. For this purpose, the criterion of achievement should be expressed in quantitative form.

It is known that the existing administrative divisions into classes, categories [ranks] and groups do not always meet the requirements of occupational screening, since they do not reflect the age-related changes in professional skill and significant variations thereof within the same class or category.

Nor can the researcher be satisfied always by far with ratings "from the top" since they often are subjective and contain not only an evaluation of the level of professionalism, but interpersonal relations existing in a group. Thus, the researcher cannot be satisfied with all methods of obtaining the characteristics of actual professional achievement to solve practical problems of psychological occupational screening.

One of the means of solving this problem is to use the "method of independent characteristics," which studies personnel by having each team member rate the professional skill of all other workers on a five-point rating scale. Characteristics are gathered by the interview method, conducted separately with each subject. The experimenter asks that only professional qualities be rated, without consideration of the personality distinctions of the person being rated.

The questionnaire sheet contains a qualitative scale with the following range of ratings: "very good," "good," "average," "poor," and "very poor." The set of individual ratings is arranged in a matrix, from which weight mean ratings of professional achievement are derived for each subject:

$$A = \frac{\sum_{i=1}^n a_i}{n},$$

where a_i is the special rating of the one interrogated and n is the number of ratings.

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Such an integral rating, which is a generalization of many [or a set] of special ratings, is a more reliable criterion than an administrative rating. When studying teams that are homogeneous in age and work tenure, the procedure for obtaining the criterion of professional achievement can be considered terminated at this point. But if the study is conducted of a production collective that is heterogeneous in age and tenure, one must take into consideration the fact that special ratings depend on the reliability of the one giving the rating, from the standpoint of the extent of his knowledge about the professional qualities of the one being rated or competence of the one giving the rating. Then the formula for mean weighted rating of professional achievement for each subject will appear as follows:

$$A = \frac{\sum a_i k_i}{\sum k_i},$$

where k_i is the coefficient of competence of the i th grader.

The coefficient of competence depends primarily on the professional skill of the grader and his work tenure. For this reason, this coefficient is individual to each occupation and is calculated empirically.

In our study, the professional achievement of each engineer examined was rated by work assigners and engineers working at the same railroad station, who knew one another well, and engineer-instructors, who directly observe the work of each engineer in their column and station masters. Since, as we have already indicated, the professional rating of achievement of the engineers examined, made by each of those questioned was not the same, we introduced the following arbitrary coefficients for different ratings: 1.0 for work assigners and engineers; 2.0 for engineer-instructors and station masters. Because of their special competence and universality of criteria, their ratings were assigned a double weight.

As a result of processing the data from the questionnaires, we obtained a successive series of average ratings, which enabled us to rank the engineers according to level of professional achievement. This characteristic, which is the result of generalization of the opinions of a large group of specialists, is highly reliable. Being integral, it levels out the significance of individual unobjective characteristics, the presence of which cannot, of course, be totally excluded.

The individual data obtained from the "typological tests," as well as data referable to different experimental parameters and overall rating of work in the modeling experiment, were compared to the ranked order of professional ratings. In addition, the same parameters were compared by the method of nonlinear correlation.

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In general, the experimental procedure consisted of the following: first the engineer was tested by methods directed toward evaluation of the main properties of the nervous system, then he participated in an experiment simulating his professional activity. Finally, an experiment was conducted to define the main properties of the nervous system.

In our statistical analysis of the data, the parameters of nervous system properties obtained in the first and second tests were considered as independent, separate indices.

Duplication of "typological tests" before and after monotonous and intensive work had to increase the accuracy of the final evaluation of the role of nervous system properties in the professional work of our subjects.

Before we discuss the results of correlative comparisons, we should dwell briefly on the data referable to rating the professional achievement of the subjects.

As a result of processing the data from the questionnaire for each of the groups, we obtained a successive series of ratings (from 2.6 to 4.8 for the first group and 2.6 to 4.5 for the second).

Table 10 lists data obtained from comparing professional achievement of engineers with prominence of such nervous system properties as strength and lability.

A scrutiny thereof shows that neither the method of rank correlation nor the method of nonlinear correlation demonstrated significant relationship between strength and lability obtained in the "typological tests" and ratings of professional achievement of the engineers we examined.

Since there were individuals with high professional skill, as well as engineers with a much lower level of achievement, in both groups of engineers tested, it is interesting that there was no correlative relationship.

On the one hand, this fact is, of course, not enough to deny the role of properties of the nervous system as a condition favoring effective mastering of the occupation of engineer. In other words, on the basis of this fact one cannot state that the strength and lability of the nervous system (according to process of excitation) are not useful qualities for an engineer. However, on the other hand, it should be conceded that, within the framework of the group we studied, neither strength nor lability manifested themselves as factors of decisive significance in achieving a high level of professional skill in engineers.

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Table 10.*

Parameters comparable to professional achievement	Correlation indices	
Coefficient b (light before work)	-0.125	0.236
VR/VR [reaction time?] ratio (light before work)	-0.091	0.108
Coefficient b (light after work)	-0.090	0.201
VR/VR (light after work)	-0.093	0.111
Coefficient b (sound before work)	-0.052	0.099
VR/VR (sound before work)	0.053	0.269
Coefficient b (sound after work)	0.094	0.094
VR/VR (sound after work)	-0.025	0.79
CFFF (before work)	0.082	0.206
CFFF (after work)	0.020	0.218

*The first column lists coefficients of linear correlation and the second, correlations (y/x) reflecting professional achievement as a function of value of corresponding parameters.

The results of our experiment showed rather convincingly that formation of such a level can succeed not only in individuals with rather marked expression of the above properties, but in those without these traits. As in the cases discussed by Ye. A. Klimov, when acquiring the skills of an engineer, a wide diversity of individual variants of "typological compensation" in the course of learning professional skills is apparently significant. Moreover, in all probability we are dealing more with the presence of equally effective and reliable variants, i.e., professionally equal individual variants of work style, than with compensation in the exact meaning of the word.

On the basis of the data obtained from correlative comparison of "typological ratings" of nervous system properties to professional achievement of engineers, it can be stated that the individual strength and lability of the excitatory process considered alone is not a factor that is significantly involved in determining the professional achievement of individuals we tested.

Let us discuss the data obtained from the experiment simulating self-regulation of professional activity of an engineer. The parameters of different engineers were compared to their professional achievement by the method of rank correlation.

The results of this comparison, which are listed in Table 11, indicate that all of the experimental parameters we singled out were significantly related to the level of professional achievement of the engineers. At the same time, we cannot single out any particular one of these parameters as the leading one, the relation of which to professional achievement of the engineer would be substantially greater than for the others.

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Table 11.

Group of subjects	Experimental parameters				
	Latency time	Total time	Errors	Missed digits	Overall rating
I (Riga)	0,56 ($p < 0,01$)	0,51 ($p < 0,01$)	0,49 ($p < 0,01$)	0,36 ($p < 0,05$)	0,54 ($p < 0,01$)
II (Kiev)	0,53 ($p < 0,01$)	0,48 ($p < 0,01$)	0,52 ($p < 0,01$)	0,30 ($p < 0,05$)	0,54 ($p < 0,01$)

Of course, this is an unexpected result, since actual train-running work is rather complex and should be implemented by an entire set of psychophysiological properties. The obtained data warrant the belief that each of the indicators used is a rather important element of professional fitness of the engineer. Even such a parameter as "missing numbers," which is indicative of the capacity to distribute and switch attention and which was found to be the least related to rating of professional achievement for our sampling of subjects, still demonstrates this relationship, on an adequate level in both groups ($p < 0,05$), as can be seen in Table 11. The significance of each indicator is indicative of the need to consider them all, and thereby renders the use of the overall rating rational.

In order to additionally check the method, it was used once more on a third group of engineers at the Tbilisi Station (45 people). The results obtained in this study virtually coincided with those described above, and thereby confirmed their reliability.

The relationship between the data obtained in the "modeling" experiment and professional achievement could be even greater if the method would take into special consideration and made evaluation of the long-term reliability of experimental performance.

The entire aggregate of data obtained by the method of modeling conditions of self-regulation of professional activity shows that it can serve as the foundation for further, more detailed development of one of the rather simple methods, which have prognostic value, for evaluating the professional fitness of mainline locomotive engineers. The assumption that the obtained characteristics of a candidate have prognostic value is based on the fact that the experiment involved testing of rather general psychophysiological traits that are the mandatory basis for successful formation of professional skills, rather than some specific professional skills that are readily acquired in the course of work experience. We should add that, since there is no external copying of professional work or of the set of its "situational conditions" in the described experiment, it is possible to design some rather universal and portable experimental devices, work with which does not require any special skills in the subjects.

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Empirical comparison of the two methods of determining the professional reliability of engineers leads us to several conclusions. The first one is, in essence, merely statement of the fact that, for the group of engineers we tested, the parameters of strength and lability of the excitatory process failed to demonstrate any consistent relation to the integral rating of professional achievement. Consequently, the use of these parameters is desirable to develop a test system for screening of mainline locomotive engineers.

The range of "typological tests" that we used is limited. However, the data obtained are, in our opinion, an additional experimental fact that questions the conception of significant and direct relationship between achievement in driver professions and levels of different properties of nervous processes determined by existing methods. Let us mention that expressly this conception must serve as the basis for using evaluation of nervous system properties in order to determine professional achievement.

It should also be borne in mind that the fact that "typological tests" are directed toward defining some property of the nervous system as such is unrelated to the conditions of any practical activity. Of course, the experiment is so designed as to address the test to the nervous system property being tested and to rule out, as much as possible, the influence of strength of other nervous system properties on the recorded parameters. It is also understandable that we want to design "involuntary methods," i.e., methods that yield data that are minimally dependent on the set of psychological factors inherent in voluntary regulation of activity. The inadequacy of such methods for the purpose of determining professional fitness becomes obvious if we consider that, in most occupations, a result is achieved expressly by means of voluntary regulation of performance, that the individual styles of successful achievement of the same professional task may vary widely, and that they are determined expressly by a combination of nervous system properties, and they are formed in the interests of most efficient use of the entire set of individual distinctions of the subject for successful performance of this task.

In mentioning the lack of conformity of the methods discussed with the objective of determining professional fitness, one must remember that they were developed primarily to solve specific theoretical problems of differential psychophysiology, rather than for direct practical use in some aspects or other of professional diagnostics.

At the same time, an experiment that addresses itself to a specific combination of mental functions and simulates some of the general conditions of self-regulation of engineer work yields data that are closely and consistently related to professional achievement of the participants in the groups examined.

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Apparently, in taking the route of modeling the psychological structure of real work and distinctions of its regulation under working conditions, we take fuller consideration of the important professional requirements of the individual who performs this work, without also predetermining the need for various psychophysiological prerequisites for its performance.

Readiness for Emergency Action as a Factor of Professional Reliability

In the literature of the last few years, it has been repeatedly stressed that it is necessary to measure the state of readiness for emergency action (REA) to solve a number of theoretical and practical problems of industrial psychology and engineering psychology. It has also been indicated that it is becoming increasingly necessary to monitor this state in view of the growth in share of occupations related to the control of highly automated systems. H. Magoun, who worked on the problem of "sensory isolation," related this state to the generation of occupations, the conditions of which compel man to be exposed to monotonous stimuli for long periods of time.

The specific distinction of work related to servicing automated systems is that the work is performed under the prolonged influence of monotonous factors. So long as a machine operates well and reliably, the operator does not work actively. Such periods of uninterrupted machine work may be quite long. At the same time, there is always a probability of machine malfunction, which could create an emergency situation in the controlled object. At such a time, the operator must become involved, as rapidly as possible, in the control process and take urgent action to eliminate the emergency. Of course, the period of relative inactivity has an adverse effect on the operator's state of REA, and it could lower appreciably the reliability of his work and, consequently, that of the automated system as a whole. For this reason, work in a rigid mode of uncertainty as to time of signals for active control action requires maintenance of constant readiness for emergency action on a high functional level.

Studies dealing with the patterns of REA are related to development of ways and means of measuring its level. At the same time, development and use of various methods of determining REA are still an unsolved problem. This is evident, primarily, when it is necessary to make a precise quantitative evaluation of REA level in the forms of work, in which the time of appearance of a signal or emergency is characterized by a high degree of uncertainty, combined with low but real probability of appearance of such a signal.

The level of REA, its dynamics and fluctuations constitute a specific aspect of manifestation of fitness for work and, consequently, could reflect the patterns of changes therein. This enables us to use the entire set of physiological methods ordinarily used to study problems of fatigue for the study of REA. However, psychological methods for

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measuring REA have not been developed as yet. These methods should permit delving into the psychological structure of the state of REA and demonstrate its psychological distinctions. Knowledge of these distinctions is needed to solve a number of problems of practical importance, in particular, occupational screening for operator professions. Development of psychological methods for quantitative evaluation of this state may be of both applied and great theoretical value to engineering psychology.

S. G. Gellershteyn, who analyzed methods of measuring fatigue, divided them into two groups. The first group consisted of methods that measure incidental signs that are related in some manner or other to diminished efficiency [fitness for work]. These methods, to which all physiological measurements can be classified, were characterized by S. G. Gellershteyn as indirect. He also noted that there were methodological procedures that permitted demonstration of changes in efficiency. These procedures included psychological methods, which were named direct methods of determining the level of efficiency.

Analysis of operator work, as compared to other types of work, shows that the specific distinctions of this activity do not permit the use of direct methods of measuring efficiency for it. This activity is characterized, as we know, by a state of expectation, a state of readiness for emergency action in response to a signal, the time of appearance of which is uncertain. Consequently, we are not dealing here with the production of some product, the amount of which could show the dynamics of efficiency within a given period of time.

Development of direct methods for measurement of REA level could become the foundation for application of psychological knowledge to solve a number of practical problems, such as development of means of insurance, methods of professional screening, etc.

It is of enormous importance to all forms of operator work to maintain a high level of REA. However, there are also sectors of the national economy where this is of particular practical importance. The professions for which the role of this state was recognized long ago include that of a railroad engineer. In railroad transport practice, the state of REA was named vigilance [or alertness]. It is expressly vigilance, as a specific form of REA, that plays the decisive role in driving a locomotive under monotonous working conditions.

Any accident related to a subjective factor in the work of an engineer contains two elements, the accident situation (for example, damaged track, car or tractor stuck on the crossing) and the specific state of diminished REA. An accident usually occurs when both elements are present. Consequently, a state of diminished vigilance can be interpreted as the internal, psychophysiological precondition for occurrence of malfunction, emergencies and accidents.

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Engineers and supervisors in the area of railroad transport are well aware of the significance of vigilance, and for this reason designers aim to develop more and more new instruments that are called upon to maintain engineer vigilance on a high functional level. However, in some cases, some rather strange variants of such devices are proposed. For example, some time ago a bicycle saddle was proposed as an engineer's chair. The expectation was that if an individual fell asleep he would fall off this uncomfortable seat. Of course, such means of maintaining vigilance could not find practical applications.

There are other devices that became quite popular, although they do not have deep enough scientific substantiation. For example, in some segments of railroads an alerting instrument is used, which emits a high-tone signal every 1.5 minutes. Upon receiving such a signal, the engineer has to release a lever, which is situated near the ceiling of the cab in some cases. If the lever is not moved within a few seconds after the signal the train stops automatically.

This signal is emitted over the entire run. It works night and day, over the span between stops and when passing through a railroad station, when the engineer has enough to worry about without it. In some cases, the necessity of getting up and depressing the lever every 1.5 minutes is a serious hindrance to the work. Time studies conducted by N. V. Malikov during actual train-running work revealed that 28% (depending on the series of runs, segments varying in road conditions, intensity of traffic, use of recuperative braking, etc.) of all depressions of the vigilance lever (VL) occurred simultaneously with the performance of operations to run the locomotive. And, as shown by analysis of speedometer tapes of test runs, there were not uncommon instances when the engineers were compelled to interrupt control operations to depress the VL on time.

But the main factor was that the number of times restrictive signals were disobeyed and other incidents occurred on these runs did not diminish appreciably. This means that the alerting instrument of the type described cannot be considered a really effective means of maintaining REA.

Analogous studies are also being conducted with reference to motor vehicles. Efforts were made to develop an automatic instrument that would prevent a driver from falling asleep at the wheel. This "vigilance indicator" is based on continuous measurement of changes in muscular tension of the eyelids. When muscular tension is below a specific, predetermined level, the signaling device is operative. However, according to the authors' statement, this instrument is not suitable for wide practical use.

The objective of a monitoring system is to determine the state of an engineer in which he cannot implement safe travel on the train.

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So-called "dead man instruments" are used on a number of railroads, which refer to a handle or pedal that the engineer depresses constantly when the train is in movement; there is automatic stopping of the train if they are released. These devices conform with specific operating conditions (low intensity, low speed and weight of a train), and therefore they are not suitable for railroads with high intensity and speed of travel. It is then necessary to make a more refined evaluation of the condition of the engineer during train-running work.

In principle, an ideal solution to the problem of monitoring vigilance would be a system capable of evaluating conformity of the sequence of actions by the engineer with the meaningful information he receives. However, it is difficult to create such a monitoring system, since we do not have the equipment that could receive and properly assess such information. In this regard, of interest are some examples of using a program prepared in advance for actions by the engineer over a specific leg of the run, to which the engineer's actions during the trip are compared. But even in this case, if the engineer's actions do not conform with the program, again a high degree of vigilance will be required of him. The existing system does not provide the needed level of evaluation of all factors determining an engineer's vigilance.

In what direction should we search for a solution to automatic insurance of the driver against so-called "blanks," falling asleep and, in general, drastic reduction of REA? Today a definite answer can be given to this question. The signal should go on at the moment and only at the moment when a change in functional state has already begun, i.e., when it is indeed necessary to deliver an alerting signal.

The work of B. F. Lomov and A. I. Prokhorov, who raised the question of automatic monitoring of the operator's condition, is of considerable interest in relation to the problem of maintaining REA in emergency situations. The operation of an alerting instrument should be based on expressly this principle, and it should have the following basic circuit: man (his state)--equipment recording impulses indicative of loss of alertness--waking signal.

Thus, vigilance as the degree of functional readiness of systems of the brain is the object of psychological research directed toward rationalization of labor. However, before developing practical measures related to vigilance, it is imperative to learn which patterns govern the dynamics of this professionally important state in the course of a more or less long period of work. This chapter deals with some direct, actually psychological, methods of measuring the level of REA.

Under industrial conditions, one generally determines the degree of a man's readiness for some action on the basis of speed of performance of this action. However, in such cases, it may be difficult to single out specifically the effect of his state of readiness for the work action

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and its real contribution to increasing the speed of a performed action. After all, the speed of psychomotor actions is not determined solely by the degree of readiness for them, but by an entire series of other factors (general activation, refinement of action, type of higher nervous activity and others).

The main circumstance that causes us to question the direct method of measuring REA is referable to individual differences between people in capacity to maintain REA, which are masked when one measures the speed of motor reactions.

If the same result is obtained when measuring the response time of two different people, it by no means signifies that they are both equally ready to react to a signal. One of them may be less vigilant, but his individual traits enable him to react rapidly, while the other, who is much more vigilant, can react more slowly at a given time by virtue of individual distinctions of his reactive motor system. For example, responses differing in time may result from the same level of readiness but different average reaction time inherent in these subjects.

Consequently, the average reaction time which, as we know, is subject to interindividual variability, is not suitable in its absolute value for measurement of vigilance as a state of REA. This difficulty has been overcome to some extent in experiments where the ratio of average time required to perform a specific action to the time of this action at a given moment of work was used as the parameter of vigilance. It was considered that if an individual demonstrates the reaction speed of which he is capable at the time of performing work, his readiness for action at this time constitutes 100%. If, however, he reacts more slowly, this figure will change proportionately to the increase in working reaction time and, finally, it could go down to zero in cases of complete loss of vigilance, for example while asleep. This index of vigilance was named the coefficient of working set (CWS). V. N. Pushkin and M. M. Filatova discovered certain patterns in the dynamics of REA on the basis of using this index.

Figure 10 illustrates the typical signs of this state under conditions of monotonous work, and it clearly demonstrates the following parameters of the vigilance curve: mean level of the curve, range of fluctuations, time of appearance of critical points (time of drastic decline of CWS) and number of such points.

The dynamics of REA studied in the works mentioned represent the overall characteristic of this state, which apparently contains several "elements," including a psychological and physiological one. At the same time, it is of considerable interest to isolate the actual psychological element of vigilance. A more refined indicator of level of active expectation of a

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signal must be used to solve this problem, along with the vigilance indicator already used.

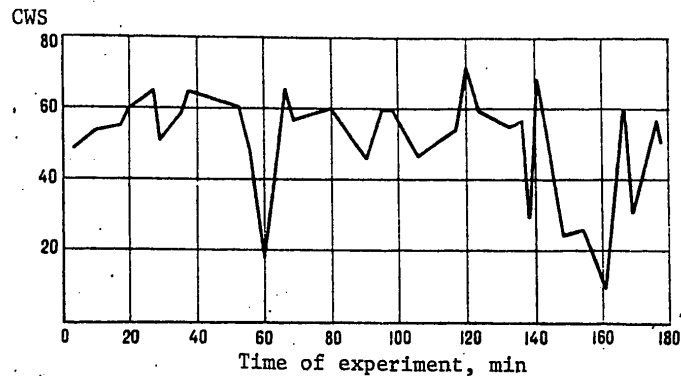


Figure 10. Dynamics of vigilance in the course of monotonous work

In developing such an indicator, we proceeded from the following considerations. During operator work, as well as that of railroad engineers, all signals to which they must react can be divided into two groups: signals delivered with and without warning.

It is known that the reaction time is quite different for these signals. There is every reason to believe that if these two groups of signals are delivered under the above-described experimental conditions and a curve is plotted for each of them, the difference between the two curves can be interpreted as an indicator of contribution of the psychological component of level of active expectation. If the difference between responses to signals with and without warning is insignificant, while the speed of the reactions proper is high, this may indicate that the warning signal does not play a large role for a given individual, since he is capable of maintaining REA for a long time. Conversely, when there is a significant difference between the above levels, we can state that the preliminary signal is mandatory for rapid reactions.

This difference acquires maximum significance under working conditions that require very rapid reactions, particularly when man must be ready for rapid actions, whether or not a warning signal is given.

This indicator, the difference between level of reaction to signals with and without warning, was used by us to study the psychological component of REA. Let us call it the index of difference P.

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In order to assess the significance or validity of this index to work, it was necessary to relate its value to an "external" criterion, an indicator of occupational achievement of a representative of a profession in which REA plays the leading role; in this concrete instance, the railroad engineer operating a mainline locomotive was the object of our study. We determined such an "external" criterion in quantitative form by the "method of independent characteristics."

As a result of processing the data, we obtained a successive series of ratings (from 2.14 to 4.71), which enabled us to rank the engineers according to level of their professional achievement. All values within the extreme ratings of professional achievement were divided into three groups, with 3.0 and 3.9 as the dividing values between groups. The group of engineers with the highest rating (over 3.9) was arbitrarily called "good"; the group with ratings of less than 3.0 was called "poor"; the intermediate group (ratings of 3.0 to 3.9) was called "average."

A total of 56 engineers participated in the experiment. The method of the experiment consisted of the following: Under laboratory conditions, working on a "running tape" device, the subject had to observe a horizontal moving tape, on which geometric symbols were traced (rectangles and squares) and keep continuous track of symbols specified by the experimenter. This monotonous, "tiring" activity in itself is merely a way of inducing a decrease in vigilance by the background, since the subject had to constantly anticipate the appearance of two types of signals of special significance among other signals. Appearance of a red ("emergency") signal required the fastest possible motor reaction by the subject. Appearance of a yellow signal, while it did not require a reaction, warned of the appearance of a red signal within a certain time that was not exactly specified, from 5 to 25 s. Each experiment lasted 3 h.

When we processed the experimental data, we plotted separately two reaction curves referable to signals with and without warning.

We used the following methods to determine the above-described index P:

1. We determined the difference between averaged reaction times obtained with emergency signals and with signals that had a warning.
2. We estimated the area between the curves shown on the graph.

We calculated the coefficients of rank correlation between the data obtained with each of these methods and rating of professional achievement of the engineers studied. They were found to constitute $r_1 = -0.53$ and $r_2 = -0.72$.

These values indicate that the proposed criterion reflects quite adequately the qualities of engineers that are significant to their professional work.

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It must be noted that the criterion of level of readiness P, calculated by the second method, is more reliable, since it permits consideration of a greater number of curve elements.

However, such evaluation of REA seemed insufficient to us. Analysis of the obtained data gave us grounds to search for other different traits, since individuals with the same P index could present different curve patterns, depending on the presence of critical points and depth of decline of the vigilance curve at these points. For this reason, we introduced an additional criterion, the mean-square deviation of time of all reactions to an emergency signal from the mean value as an indicator of stability of level of REA.

The coefficient of rank correlation of this index with ratings of professional achievement of engineers was found to constitute 0.52.

An analogous index was calculated for the curve of reaction time to a signal with warning. In this case, the coefficient of correlation between stability of REA and ratings of achievement of the subjects was quite low, 0.12. For this reason, it may be assumed that the level of professional achievement is more closely related to the nature of reactions to emergency signals.

Concurrently with evaluation of the reliability of the proposed criteria according to value of the coefficient of rank correlation, we evaluated them according to level of statistical significance of difference between arithmetic mean values of the indices obtained for the groups of "good," "average" and "poor" engineers. A comparison of indices of stability and level of REA of "good" and "average" engineers revealed that the criterion was rather high with a confidence level over 99% ($p < 0.01$). The confidence level of differences between indices for "good" and "poor" engineers was close to 95% ($p < 0.05$).

It must be noted that the traits demonstrable by the proposed criteria, though they are necessary, are not enough to assess successful professional performance. Of course, there are also other human traits that affect the level of his achievement but are not reflected in the index we used.

A probable individual characterization of a subject can be obtained on the basis of comparison of his experimental data to the extreme values of both criteria for each group, which are listed in Table 12.

As an example, we submit the graphs for three engineers that have defined work characteristics: "good," "average" and "poor" (Figure 11).

Graph 1 illustrates curves for engineer G., who has a high index for his work characteristics, 4.51. We see that there is only a small

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difference ($S = 2.614$) between the level of the curves for reaction time to signals with warning and to emergency signals. The index of stability of the curve referable to emergency signals is $\sigma = 0.01$. These indices are higher for engineer K. (graph 2) whose professional performance was rated as 3.80 ($S = 10.260$; $\sigma = 0.26$). Finally, for the third engineer, M. (graph 3), there is a substantial difference ($S = 22.640$; $\sigma = 1.00$) between the curves showing time of reactions to signal with warning and the emergency signal.

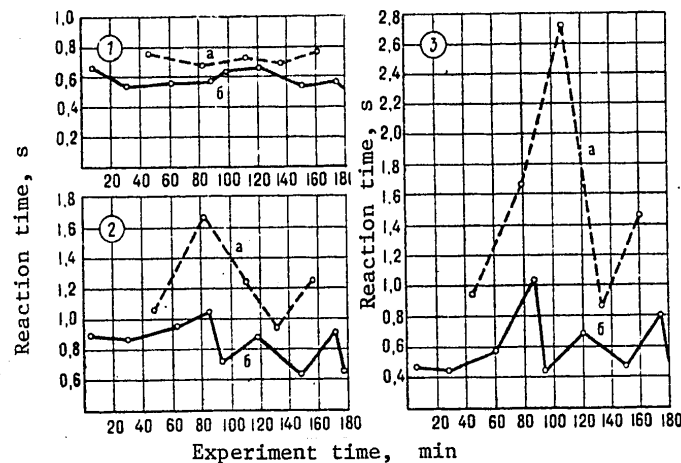


Figure 11. Dynamics of oculomotor reaction time for three different subjects

Table 12.

Rating of engineer	Criterion of professional achievement	Rating criterion	
		S	σ
"Good"	>4.07	<6.100	<0.18
"Average"	$2.78-4.07$	$6.100-11.500$	$0.18-0.47$
"Poor"	<2.78	>11.500	>0.47
Coefficient of correlation		-0.72	-0.52

Typically enough, in this case the coefficient of professional achievement constituted 2.72.

The curves shown in Figure 11 illustrate quite clearly the difference between the vigilance curves for the three tested engineers whose ratings of professional fitness were different.

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The presence of a positive relationship between the direction of the two curves in a number of cases was an important factor demonstrated in this study. For example, on graph 3 (see Figure 11), after the 80th min of the experiment there was a drastic increase in reaction time in both cases. This identical direction of the curves is apparently indicative of certain changes in level of functional state of the body which, regardless of the personality set of the individual, affects his reaction time.

These experimental data enable us to relate the nature of the REA curve, which was the object of analysis in the works of V. N. Pushkin and M. M. Filatova, to the distinctive features in the work of an individual. In their studies, the dynamics of vigilance under monotonous conditions were examined in "neutral" subjects, for whom vigilance was not a decisive factor in their work. The professional significance of the distinctions of this curve was assessed purely theoretically or on the basis of a small amount of facts. Experimental studies of engineers, in whose work vigilance plays an unquestionable role, permit demonstration of the professional significance of the distinctive features on the REA curve. If, for example, we were to consider the dynamics of reactions to red signals, demonstrated in these experiments, we shall find that the curve of readiness of engineers is considerably more stable than the readiness curve of "neutral" subjects. This was the most prominent in engineers given a high professional rating. Evidently, the distinctions of professional work of engineers have some influence on the readiness curve also.

The drastic "drops" of REA curves demonstrated in our experiments for some engineers acquire particular importance. It is expressly a state of diminished readiness for action at a critical point that must be interpreted as the internal, psychophysiological basis of a possible accident. Of course, an accident is more likely to occur when the emergency situation coincides with the time of a critical point, which is its subjective precondition.

Analysis of the data obtained from our experiment demonstrated the significance of new criteria for evaluation of vigilance. There is every reason to believe that these indices are indicative of stability and level of personality-related orientation toward performing an emergency action under conditions of expectation of a signal, the time of appearance of which is not specified.

The rather high coefficients of correlation of index P with professional achievement of engineers indicate that these indices can be used to solve some important practical problems related to rationalization of work in occupations, in which a high level of REA is an important element.

* * *

Analysis of the results of the experimental studies enable us to raise the question of psychological structure of a specific working state,

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such as readiness for emergency action under monotonous working conditions. A comparison of the results of this study to data in the literature, referable to analysis of the problem of efficiency, enabled us to distinguish three elements forming the structure of REA.

The first element is the image of the structure of action that is required in response to some emergency signal or other. In the work of an operator or dispatcher, this is a sequence of actions directed toward normalization of the state of the controlled object; in the work of a railroad engineer, this refers to manipulations of locomotive controls, the controller and brake, by means of which the speed of travel is changed or else the train is immediately stopped. In experiments dealing with vigilance this is a simple motor reaction. All of these acts, which are coded in some way or other in the brain of working man, can be characterized as images or information models of actions. With the occurrence of an emergency situation, the operator or engineer actualizes the reaction model that conforms with the signal.

The general psychological state that assures rapid actualization of the required work action in emergency situations should be considered the second element of REA. The level of this state is determined by the complex interaction between many systems of the body and, particularly, the functional level of the nervous system of a working man. This element of readiness for action can be described as the integral psychophysiological component.

The actual psychological orientation of the personality toward performance of required actions in the event of an emergency signal is the third element of the state of REA under discussion. This element is manifested by man's conscious readiness to perform the required actions as soon as the appropriate situation arises. The typical distinction of this personality orientation is tension, struggle against decline of readiness for action, which implies a certain volitional effort. The personal orientation toward actively maintaining REA occurs in work that is related to responsible performance under monotonous activity, at the exact time when man notices a drop of functional level of his activity, when he begins to realize that this decline of vigilance could be dangerous to the entire object that he is controlling.

All three elements of readiness for action are expressed differently in operator work. Thus, the first element, image of the structure of required action, is manifested by correctly performed actions. Erroneous operator actions can serve as an indicator thereof. Correct performance of required acts is also of some significance to the other two elements. Thus, when there is diminished activity of various functional systems, a man may perform a slower action, one action instead of another, or the wrong sequence of actions. However, diminished efficiency or even impaired performance due to decline of level of functional activity is most often demonstrable when the work skill has not been entirely mastered.

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The second component of readiness for action is the most prominent when there is complete development of a skill, when all the required actions are automatic. In this case, the overall psychophysiological element of REA inevitably reveals itself in various time factors and, primarily, delay in the required work reaction. However, as has already been repeatedly mentioned, certain difficulties are encountered in making a direct measurement of level of functional activity by means of reaction time, since each man has his own inherent reaction time. For this reason, it was proposed to measure the relationship between a man's reactive capabilities and reaction time at a given moment of work (CWS), rather than speed of reaction.

The third element of readiness for action, the personal orientation toward prompt and accurate performance of action required in emergency situations, turned out to be the most difficult to record objectively. This psychological, personal [personality] element could not be defined by either the speed of reactions or even CWS level. This last mentioned parameter unquestionably contains the third element to some degree or other, and it influences the REA index. However, as we have already mentioned, the need arises to differentiate between the psychological element proper and the integral psychophysiological index. In our study, such differentiation was made by means of index P of difference between level of reactions to signals with and without warning.

As shown by the results of this study, the level of P consistently characterizes certain individual personality traits of a working man. This is indicated by the values of correlation between index P and professional achievement of the tested engineers.

Of course, professional achievement, as a specific trait of railroad engineers, is by no means limited to the REA level. In describing an engineer, the interviewees were governed by a rather wide set of personality traits: discipline, organization, ability to run a locomotive with high economic indicators, etc. The rating expressed in a grade was the overall indicator of the entire set of traits of the engineer as a worker. And this entire broad set of professional and personality traits of an individual was found to be quite definitely related to such a psychological trait proper as the capacity to maintain a rather high level of REA.

Thus, on the one hand, the index used in this study of the difference between reaction levels can be used in the practice of professional screening. A high correlation between S and professional achievement ($r = -0.72$) can serve as grounds for recommending it for practical use. On the other hand, our results enable us to make the next step in analyzing the psychological mechanisms of REA as a certain distinction of the personality.

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In the theoretical aspect, it is expedient to relate the state of REA to the concept of "set," which is being developed by the school of D. N. Uznadze. The representatives of this school interpret the concept of set as "readiness for a certain activity," a state that "is founded on the patterns of activity of the entire organism." The state of set "consists of adjustment, adaptation of the integral subject that causes manifestation of expressly the mental and motor acts, which provide for adequate, contemplative or effective reflection of a situation." In other words, the set is manifested by the subject's adjustment for a specific activity, it causes occurrence of mental actions that are required for purposeful activity. The school of D. N. Uznadze was the first to call attention to the fact that "not only creation of potential 'predisposition' for action, but actual regulation of the dynamics of action or reflection after the actions are formed" are the functions of set.

Thus, set is defined as an integral personality-related state that precedes some activity or other and determines its performance. It is not difficult to see that readiness for emergency action, which we are studying, conforms entirely with this definition. However, analysis and comparison of the facts indicate that set, as readiness of an operator for emergency actions, and set, as the mechanism of illusions studied by D. N. Uznadze and his proponents, are states that differ from one another in their concrete psychological nature. In one case, we are dealing with actualization of object models formed in prior experiments, and in the other with maintaining the capacity to react to an unexpected signal at a specific level.

A comparison of these states shows that there are different concrete forms of set as integral personality-related readiness for action.

Many researchers relate the state of REA or state of vigilance to a specific state of wakefulness. It has been demonstrated that the different degrees of attention, from scattered to highly concentrated, are strictly correlated with specific levels of wakefulness. According to D. Lindsley, V. Block and R. Hernandez-Peon, the nerve structures that control levels of wakefulness are involved in processes of directed, selective attention. These authors make a distinction between "passive," "nonspecific" and "specific" waking states.

The studies of neurophysiologists are of great interest from the standpoint of demonstration of mechanisms of vigilance.

In the works of G. Walter, H. Magoun, A. A. Ukhtomskiy, M. I. Vinogradov and N. A. Bernshteyn, there are indications of neurophysiological bases of vigilance as a state of readiness for action. In expounding the concept of physiological operational rest, A. A. Ukhtomskiy interpreted it as readiness for action, i.e., an active state that may be on different

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functional levels, rather than a self-evident physiological state. He wrote: "A more highly organized capacity for operational rest, along with more organized, immediate readiness for action."

N. A. Bernshteyn related the mechanism of readiness to excitation of conditioned association systems, while G. Walter related it to the selection and storage of sensory information having a direct bearing on some action or other. He recorded so-called "waves of anticipation," which appear in the frontal cortex in the interval between warning and triggering signals. The amplitude of these slow potentials reflects the degree of subjective probability of appearance of triggering signals and, mainly, the subject's attitude to the experimental situation, his readiness to perform a task.

All these studies revealed that the work process and its ultimate result depend on a number of psychological and psychophysiological factors.

The problem of readiness for action is one of the most important problems of psychology of activity in general. For example, deserved attention is given to it in studies of sports activities from the standpoint of increasing their results. In these studies too, we find much of value for the general description of the state of readiness.

There is a certain interpretation of psychological readiness in sports psychology. To sum up the statements of different authors, we can list the following features of this state: in the course of raising the level of readiness, a feeling of confidence appears and is reinforced, a static condition or excessive tension diminish, there is improvement of general condition and mood. All this, of course, cannot fail to affect and really affects a number of mental processes: intensity and stability of attention, scope and rate of visual perception, and reaction speed reach maximum levels. Analysis of the results of studies of this state indicates that there is selective formation of readiness for action.

The findings enable us to state that actualization of readiness for action can be considered an element of the general process of self-regulation of a given specific activity.

At the present time, it can be stated with certainty that formation of readiness for action is a special objective of psychological training of any specialist, be it preparation of an athlete for a competition or professional training of a locomotive engineer for his job.

Short Variant of Method to Determine Readiness for Emergency Action

The experimental data obtained revealed that the proposed method meets one of the professionally meaningful requirements imposed by the specifics of the work of a mainline locomotive engineer. However, in spite of the rather high coefficient of correlation between the index obtained and

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professional achievement of the engineer, the method we propose has a number of practical and methodological flaws. They include the following: cumbersome equipment; length of experiment (each lasted 3 h); burdening the subject with several operations in the course of the experiment (counting squares, marking each 10th box, which aided in holding vigilance on a specific level throughout the experiment).

All this compelled us to try to develop a variant of the method that would permit faster implementation, in view of the many candidates to be submitted to professional screening, while retaining all of the basic aspects of the above-described method of predicting the level of REA.

The hypothesis was expounded that simplification of the work process in the experiment would create greater uniformity, intensify the monotony factor, which would permit reducing the experiment to 1 h instead of 3 h and make it possible to examine more effectively the performance of an operator-engineer in the anticipation mode.

A laboratory experiment with modeling was conducted in an isolation booth, using an instrument we designed for testing vigilance, to examine the state of REA.

The instrument consists of two units, one for the subject and one for the experimenter. The front of the subject's unit consists of an operational white field, on which there are 60 radially oriented slits, 3 mm in width and 8 mm in height, at 6° intervals, which are equipped with dull-finished filters. When the instrument is turned on, each slit in a clockwise direction is successively lit up with a flash of light at 1-s intervals. Each flash is accompanied by a click.

According to the instructions, disruption of flash sequence is a signal for action, i.e., when the light skips a slit. The subject, who is seated by the instrument placed on eye level at a distance of 60-65 cm, must react by rapidly depressing the reactive key, as a result of which the flash of light returns to the position prior to the "skip." Such signals are given either with or without warning. When the signal is given with warning, a yellow lamp lights up in the center of the field, and it "warns" the subject that there will be a skip within an unspecified time to which he must react quickly. The interval between the warning signal and emergency signal ranged from 5 to 25 s. The experiment lasted 1 h. In this time, 12 command signals were delivered, 6 of which were with a warning and 6 without, i.e., urgent ones. The signals were delivered following a program that was the same for all subjects and prepared by the law of random distribution.

Since the signals were presented in no particular pattern, the subject had to constantly watch the movement of the light spot on the operational field. The intervals between two consecutive command signals ranged from 4 to 7 min.

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In this experiment, a high "monotonous" load was created by the specifics of the test itself, namely, uniformity and frequency of recurrent stimuli (spot of light and click).

The experimenter's unit consists of a monitoring and measuring device that records the latency period of reactions and erroneous actions by the subject. Depression of the button upon delivery of warning signals was recorded as the wrong action.

A total of 95 railroad engineers (2 columns) with work tenure of 5 to 18 years participated in the experiment. The significant tenure enabled us to obtain a reliable evaluation of professional fitness for each of the subjects. As we have already indicated, this rating was derived as the average of ratings given on a 5-point scale by each engineer for all of the other participants in the experiment, who worked in the same column and knew one another well. In addition, we took into consideration the evaluation made by instructors and station masters, who constantly made special checks of engineers' performance in the course of trips with them.

As a result of processing the results of the questionnaires, we obtained a successive series of ratings from 2.7 to 4.6, which enabled us to rank the engineers according to the level of their professional achievement. All values within the range between the extreme ratings were divided into three groups, the separation points being at 3.3 and 4.0.

The subgroup of engineers with the highest professional rating (4.0) was arbitrarily called "good"; the one with a rating of less than 3.3 was called "poor" and the intermediate group was called "average."

We used the method of rank correlation to compare the experimental indices to the indices of professional achievement ("external criterion").

In all cases, the main experiments were preceded by training tests, in the course of which the subjects learned the instructions well and acquired the necessary work skills.

We calculated the difference between average reaction times to emergency signals and to signals with warning to find index P.

In addition to index P of difference, we calculated the mean-square deviation of time of all reactions to the emergency signal from the mean value, as the index of stability of REA level.

Statistical analysis of the obtained data revealed that these experimental indices are meaningfully related to the level of professional achievement of the engineers. They constituted $r = -0.63$ (with $p < 0.01$) in the first case and $r = -0.31$ (with $p < 0.05$) in the second.

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Table 13.

Rating of engineer	Professional rating K	Criterion of experimental rating	
		P	σ
"Good"	>4.0	<0.18	<0.29
"Average"	4.0-3.3	0.18-0.24	0.29-0.54
"Poor"	<3.3	>0.24	>0.54
Coefficient of correlation	---	-0.63	-0.31

The actual meaningfulness of the obtained data warrants consideration that both indices are substantially important elements of professional fitness of engineers. This is indicated by the values of coefficients of correlation of indices P and σ with the professional achievement of the subjects.

The probable individual characteristics of a subject can be obtained on the basis of comparing his experimental data to the extreme values for both criteria for each group, which are listed in Table 13.

A higher coefficient of correlation between index P and professional achievement, which was obtained by the method we propose, indicates that this method reflects most adequately the specific traits of an engineer that are essential to his professional performance.

Thus, our results warrant the conclusion that index P of the difference in reaction levels, which we used here, can be applied in the practice of professional screening of railroad engineers.

Evaluation of Stability and Persistence of Individual Indices in Studies of REA

In any experimental study of professional fitness, the results of which presume to have prognostic value, one of the most important elements is evaluation of stability and persistence of individual parameters [indices] of individuals examined. A decision is made as to the degree of fitness of a given individual for a given form of work on the basis of consideration of these indices. Indeed, if a specific level of some psychological property or trait, which is formed in the individual, is taken as a screening criterion, its relative persistence and minimal capacity for training is implied a priori in the system of one-time testing. As a rule, the procedures for psychological examination for screening purposes involve single use of test methods. Under such conditions, one cannot determine the stability of individual parameters, since it may be quite difficult, for a number of reasons, to examine candidates a second time. This gives validity to the statement that a test model does not solve the problem of mastering a profession and, perhaps, that individuals deemed

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unfit actually fail to meet the test requirements, rather than the requirements of an occupation.

This thesis is of substantial importance in screening operators of transport. In the first place, in the course of rationally planned training, one acquires skills to control and service systems rather rapidly (for this reason, we cannot rule out the possibility of rejections during the screening process of individuals that could be capable of successful training). In the second place, the work of transport operators is, as we know, characterized by a number of specific distinctive features, which impose high demands, not only with respect to levels of required psychological properties and traits, but persistence thereof with regard to emergency situations, i.e., reliability of performance.

All of the foregoing enables us to single out the range of problems that must be solved in order to use the modeling experiment method in screening for a concrete transport-related occupation. They include: determination of stability and persistence of the proposed parameters of occupational fitness in repeated tests and determination of the prognostic value of the method, which is related both to the possibility of developing a given psychological trait or set of properties and traits in the course of professional activity, and persistence thereof in diverse emergency, extreme situations.

We conducted a series of experiments directed toward the following, in order to test the method of determining REA under monotonous conditions: 1) determination of prognostic value of developed criteria of occupational fitness by the method of repeated testing of REA level in the same group of subjects for 3 years (checking stability of individual parameters); 2) effect of conditioning [training] on parameters of professional fitness according to REA; 3) evaluation of endurance of individual parameters of REA levels when creating conditions that disrupt significantly the normal operating mode. Since the engineer receives most of the most important information visually, we induced temporary impairment of normal function of the visual analyzer as "stress" conditions.

Apparently, it could be assumed that organization of long-term psychodiagnostic studies of operators according to the proposed psychological parameters would yield an objective picture of the dynamics of their professional reliability. However, the series of repeated studies demonstrated an interesting empirical pattern.

In the first study, the coefficient of correlation between professional achievement of engineers and REA index ($r = -0.72$, with $p < 0.01$) is higher than the same coefficient obtained in the second examination 1 year later ($r = 0.68$, with $p < 0.01$) and another after 2 years ($r = -0.62$, with $p < 0.01$), i.e., the reliability of the test diminished somewhat. The number of "critical points" on the vigilance curve increased, which suggests that there is some deterioration of level of readiness for emergency action.

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There is a logical explanation for the seemingly paradoxical findings, if we consider in detail the cause of such changes, a factor whose influence has not been sufficiently covered in the psychological literature and is often overlooked in psychodiagnostic studies.

As a rule, studies of engineers related to development of methods of professional screening are conducted in a specific, expertise-oriented situation. This is due to the fact that when the engineer comes for the examination, he is told that his skills, speed of reactions, attention, resistance to monotony, etc., will be "tested." True, neither the instructions nor additional methodological directions prior to the experiment contain indications of possible dismissal from the job in the event his marks are not high enough. However, in view of the fact that every engineer regularly undergoes medical certification, pre-run examinations, as well as other check-ups, the results of which may be that he will be removed from the run or transferred to another job, the psychological examination is interpreted as a sort of additional check of their potential capabilities. For this reason, an engineer comes to the first test with a rather high level of motivation, but experiencing considerable emotional tension.

He does not know how the experimental results will affect his future, and this compels him to give his best at the first test.

When reporting for the experiment a second time, there was substantial decrease in tension, which affected the results as a whole, by virtue of the fact that, in the first place, changes had not occurred in the past year in the professional status of the subjects because of the prior tests and, in the second place, the engineers were quite familiar with the experimental conditions. This affected both the correlation between the curves of reaction time for delivered signals and number of critical points.

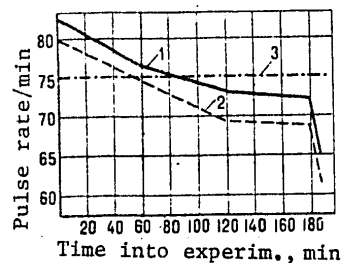


Figure 12.

Dynamics of change in engineers' pulse rate in the course of 3-h experiment under monotonous conditions

In our opinion, it is interesting that there was a decline of pulse rate during the second examination a year after the first (Figure 12). This figure clearly illustrates the decline of pulse rate during the second examination, both before the experiment, which we shall discuss in more detail below, and throughout the 3-h experiment under monotonous conditions. This was also reflected in the psychological findings. Thus, the second time we observed considerably less often signs of tension, disorganization, uncertainty, anxiety, etc.

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Consequently, by submitting the same subjects to the same type of load, one can derive a conclusion, on the basis of the findings, that a repeated experiment cannot disclose the true capabilities of a subject, for a number of reasons, and they are better demonstrable in the first test. The direct statements of subject engineers were also indicative of decrease in general emotional tension.

Thus, the results of this series of experiments convinced us that the REA parameters depend significantly on subjective factors, i.e., change in attitude toward experimental conditions.

We were also impressed by the pulse rate data obtained before the experiment conducted to determine REA (see Figure 12). Thus, before the test, the pulse rate of the engineer group was somewhat higher in both the first (85/min) and second (79/min) cases, as compared to the pre-run check-ups at the medical center of the locomotive depot. This indicates that the expertise-oriented situation, which is unquestionably a rather potent stress factor and has varying degrees of an emotional effect on all engineers examined, could serve as a distinctive model of motivational mechanisms that are involved in maintaining steady "working" tension under real working conditions.

Thus, there is reason to believe that the differentiating prognostic capability of professional screening methods depends largely on the subjects' attitude toward the test, on "the level of its expertism."

All this warrants the recommendation that the principle of a one-time psychological examination be followed in studies dealing with evaluation of maximum level of REA characterizing individual engineers and, incidentally, other workers.

To assess the degree to which individual REA parameters can be developed, we examined a group of 37 assistant engineers in a modeling experiment. We conducted tests with each subject three times at 2-3-day intervals between tests. To compare the obtained data, we used the nonparametric statistical criteria Z_α of signs, Wilcoxon's T criterion and Mann-Whitney's U criterion, since the distribution of values of a random parameter in samples differs from normal according to the W criterion of Shapiro-Wilkie. Table 14 lists the results of statistical comparison of sample means referable to repeated tests.

The results of statistical processing indicate that existence of training [conditioning] did not elicit substantial changes in REA levels in the tested group of assistant engineers. They warrant the conclusion that this function is relatively stable and persistent.

However, it can be assumed that numerous repetition of activity is not sufficient to establish that REA is not susceptible to conditioning.

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This hypothesis can be verified, in particular, by comparing the dynamics of this function to the dynamics of another psychological trait that is of equal professional importance to the subject. For this reason, in addition to the statistical methods we have described, the modification we chose of the method of determining professional reliability, which is based on the use of a shortage of time, enabled us to make an interesting comparison, which backed up the conclusion that the function of REA is not very susceptible to training.

The method used permitted both measurement of REA level (tracking function) and study of parameters of a motor skill simulating functions referable to actual driving of the locomotive.

Table 14.

Test	Number of tests	Sampling means and sampling spread, ms	p in relation to background	Criteria
1	37	144(-130÷430)		
2	37	136(-160÷510)	>0.05	Z α , T, U
3	37	166(-210÷520)	>0.05	Z α , T, U

Concurrent comparison of both elements forming the model of the real psychological structure of engineer work revealed that the parameters of motor skill (T_1 , total action performance time; T_2 , latency period of action) improve significantly from test to test: $T_{1st} = 4.07$ [st--start], $\sigma_1 = 1.36$; $T_{1end} = 3.07$, $\sigma_1 = 0.45$; $T_{2st} = 1.84$, $\sigma_2 = 0.69$; $T_{2end} = 1.28$, $\sigma_2 = 0.20$ (with $p = 0.01$ for both cases), whereas no significant changes in REA level were noted in the course of training this group.

In addition to the study of the prognostic value of the method of determining REA level for professional reliability, we conducted a complex study of 28 assistant engineers to assess the stability of individual indices of REA level during temporary disruption of normal function of the visual analyzer, manifested by constriction of the pupils, accommodation spasm and impaired oculomotor function.

This is, of course, a rather strong stress factor, the influence of which must be studied in detail and considered when evaluating the results of such studies.

As can be seen in Table 15, temporary impairment of normal function of the visual analyzer in a modeling experiment did not elicit appreciable changes in REA level in this group of subjects, which is indicative of the fact that this professional group is capable of maintaining REA on a high functional level with exposure to extreme factors.

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Table 15.

Experimental series	Number of tests	Sampling means and sampling spread, ms	p in relation to background	Criteria
Background	28	107(-7÷341)		
With impaired visual function	28	108(-108÷291)	>0.05	Z α , T, U
With restored visual function	28	112(-1÷333)	>0.05	Z α , T, U

Thereafter, it was interesting to track the change in individual forecasts of professional achievement by the examined group of assistant engineers in the course of an experiment. For this purpose, the obtained individual REA levels were assessed on the basis of appropriate prognostic criteria of occupational fitness, which we developed before, and they were compared to one another according to effectiveness of the proposed method.

The results of examining the individual parameters of REA are listed in Table 16.

Table 16.

Experimental series	Professional achievement rating		
	good, P<180 ms	average, 181<P<248	poor, P>250 ms
Background	24	3	2
Impaired visual analyzer function	23	3	2
Restored visual analyzer function	25	2	1

Under the conditions of the modeling experiment we used, there was no decrease in performance quality in the presence of an extreme factor. However, in a parallel additional study of distinctions of the function of attention, we demonstrated a substantial decline in productivity and accuracy of performance of "proofreading test" and "addition with switching over" in the modification of Lukauskas.

Apparently, as validly observed by V. I. Marishchuk, N. F. Kruglova and others, operator efficiency during exposure to extreme factors is characterized by some selective redistribution of functional capabilities. As a rule, the main activity is performed with greatest efficiency, and other actions in the work process are performed with constant decline of results with depletion of psychophysiological resources.

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This series of experimental studies warrants the belief that the method of assessing the level of REA, based on modeling of the real psychological structure of the work of mainline locomotive engineers has sufficient validity and reliability. Consequently, it is quite suitable for use to predict the degree of professional reliability, both in screening candidates and in periodic checks of professional engineers.

Experimental Evaluation of Emotional Stability

Psychological tension of the operator-engineer is constantly increasing, in view of the increased speed of railroad transport. This leads to increasing difficulties of man's adjustment to the environment. As the adjustment difficulties increase, there is also increase in intensity of stress situations. Emotional stability, self-control, presence of mind, calmness, composure, etc., are required of the engineer to find a way out of hazardous situations and to prevent serious consequences.

Not all engineers behave in the same way in such situations. Not infrequently, accidents, passing through restrictive signals and other incidents are caused expressly by the fact that the engineer loses his head in the presence of danger, performs the wrong actions and is not capable of prompt performance, occasionally even of elementary operations.

In determining the professional fitness of candidates for the job of engineer, probabilistic forecasting of how he will perform his duties in hazardous situations, i.e., evaluation of his emotional stability, is a problem of first and foremost importance.

Such studies have been conducted for a long time in aircraft and motor vehicle transport. Several works have dealt with demonstration of a link between emotional stability, heightened excitability of drivers and their professional work.

Some American researchers have shown that drivers who have had many accidents are emotionally less stable than those who worked without accidents. They related manifestations of various emotional states to aggressiveness which, in their opinion, is supposedly a reaction to an unfavorable mental burden and could be transferred not only to friends, pedestrians, but to inanimate objects, including cars.

The works of many Soviet authors (K. K. Platonov, K. M. Gurevich, V. F. Matveev, K. K. Ioseliani and others) deal with a description of the effect of emotional stability on the work of operators and pilots. It was shown that, in emergency situations, emotional stability can be manifested in qualitatively different forms (impulsiveness, bustling, slower actions, etc.) and associated with diverse experiences (sense of fear, lack of confidence, confusion, helplessness, etc.). The manifestations of emotional instability may also vary in severity,

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ranging, for example, from a mild state of confusion to complete mental disorganization and removal of oneself from work.

Emotions are a complex mechanism of purposeful regulation of behavior, and it is often difficult to compare their physiological essence and psychological manifestations.

The main difficulty in most studies of emotions conducted in the laboratory is that, in spite of methodological contrivances, the experimental model itself is artificial and is wanting in a number of essential elements of reality. Nevertheless, demonstration of behavioral distinctions of man in artificially complicated situations could help disclose the general patterns of his emotional reactions.

Questions related to this problem could be answered if we were able to determine the degree to which the results obtained with experimental devices simulating the conditions of train-running work are adequate for predicting the behavior of an engineer under real working conditions.

But, since this can be determined only by means of systematic comparisons of real train runs and experimental data, of course there are great difficulties.

Another method is to submit, in the course of a laboratory experiment, the subject to one of the forms of stress that is actually encountered in railroad work. A typical instance of such stress is the stress that is induced by assigning a task that must be performed under conditions of acute shortage of time and with exposure to distracting factors.

Evidently, any effort related to intensive work can be considered a stressor when there are distracting circumstances. Active interference of any type can serve as such a distraction.

In this study, we selected expressly this type of stressor. We created an experimental situation, in which there was a struggle between different stimuli. To work efficiently, it was important not to pay attention to sensory stimuli delivered as interference and to continue the main activity.

A total of 97 engineers with work tenure of 5 to 18 years participated in the experiment. In the laboratory, the subject was asked to work with the black and red number table of Schulte-Platonov, which is widely used in industrial psychology (Figure 13).

The engineer had to perform four tasks with it: successively find black numbers in the table in ascending order, from 1 to 25; find red numbers in descending order from 24 to 1; alternately retrieve black and red numbers, in ascending order for black and descending for red; while the fourth task was the same as the third, the only difference being that

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an additional emotional factor was added when reading [or counting] pairs of numbers. A tape recording of a voice reading this table aloud in the same order as was to be followed by the subject, but with deliberately faster delivery of the verbal interference than the pace of the subject, served as such a factor. The first two tasks had the purpose of familiarizing the subject with the material and methods of working with it.

20	13	14	2	9	21	10
18	16	16	4	8	6	4
22	5	12	20	24	15	15
11	19	8	23	6	11	12
3	1	21	5	14	18	1
23	24	17	17	13	9	19
10	7	2	3	22	25	7

24	6	10	18	15	5	3
9	22	22	2	17	13	14
1	13	11	5	8	20	10
15	17	24	2	20	11	1
14	21	4	18	7	23	16
7	12	21	19	23	6	16
4	19	8	24	3	12	9

Figure 13. Variants of tables used in the experiment: solid-line numbers refer to black and dotted-line ones to red

Each of these four stages of the experiment was conducted with different, but equivalent variants of the table.

Working with this method is quite complex, since it requires simultaneous performance of operations that are similar in content but different in direction.

We used a stopwatch to time the performance of each task. The subject worked in the presence of the experimenter. During the test, the experimenter did not interfere in the subject's work, but when difficulties arose, and the subject was inclined to stop working, the experimenter stimulated him and demanded that he complete the task. We used the time difference between the third and fourth tasks as a criterion of emotional stability.

Analysis of the results of this experiment consisted of comparing them to the professional characteristics of the tested engineers ranked according to Spearman.

On the basis of our objective, we also considered the nature and number of mistakes as parameters of test achievement. We classified the mistakes for qualitative analysis. The classification was based on the degree of seriousness of mistakes, which was determined according to number and significance of the overlooked elements of the instructions.

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Gross mistakes include the following: change in direction of retrieval of numbers in one of the series and change in direction of both series (switching series color).

Slight mistakes refer to "one-step" loss of direction in a series when calling one number, loss of series (temporary forgetting the last called number of a given color), skipping one or two numbers, isolated mistakes in calling color.

In addition, there were repetitions of numbers just called and repetitions of the tape.

Analysis of the results revealed a statistically significant link between the level of emotional stability according to accuracy and work pace in the presence of interference and professional achievement of tested engineers ($r = 0.69$), determined by the method of "independent characteristics."

Observation of progress of the experiment, as well as comprehensive analysis of mistakes, enabled us to make a qualitative evaluation of the subjects' work in the process of performance of the experimental task.

The subjects could be divided into three groups, according to task performance: those who did well with all stages of the work; those who did well with the first three stages and those whose work was unsatisfactory at all of the stages.

Good performance of the task referred to absence of gross errors with no more than 100-s difference between time of performance of the third and fourth tasks. Individuals who made some slight mistakes corrected them in most cases in the course of the experiment. With the addition of interference, we observed transient signs of slight confusion, "tuning out" phenomena, changes in frequency characteristics and volume of the voice. In some cases, there was a change in intonation, with appearance of emphasis in pronouncing each word.

When the work was done with gross errors and a time difference in excess of 100 s, it was rated unsatisfactory.

Such subjects usually made gross errors, could not correct their performance throughout the period of experimental work. With the addition of interference, we observed signs of marked excitement, lack of calm and composure, and restlessness. In some cases, there were signs of affective disorganization and, occasionally, complete breakdown of activity. There was an appreciable increase in performance time in the presence of interference.

To summarize this study, it can be noted that the use of the black and red table, with addition of unexpected interference, permits demonstration

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of the subjects emotional reactions, and creates conditions in which there is rather vivid manifestation of the level of their emotional stability. This enables us to use the difference in time between experimental tasks involving reading black and red numbers with and without interference as one of the criteria in the practice of professional screening. The coefficient of correlation between experimental parameters and professional achievement of tested mainline locomotive engineers can serve as the basis for recommending this criterion for practical use.

Determination of Speed of Redirecting Attention

Increased demands are made of the engineer's attention characteristics to run a locomotive. The constant burden on attention is related to the need to perceive an enormous amount of signals and working objects. Consequently, the requirement of prolonged activation of attention, with concurrent capacity for emergency redirection thereof, is essential to the professional work of an engineer.

We used the first three tasks from the above-described study using the Schulte-Platonov table to determine emotional stability as the method for determining the speed of redirecting attention.

The experiment with this table was conducted on the same group of engineers.

The first two tests furnished data pertaining to the time spent by the engineer to find black numbers in ascending order from 1 to 25 (A) and red ones in descending order from 24 to 1 (B), while the third one gave us the total time spent to find black and red numbers (C). We calculated time T of redirecting attention using the well-known formula:

$$T = C - (A+B).$$

A comparison of experimental testing of redirection of attention to professional achievement of engineers revealed that those for whom the mean time for redirecting attention exceeds 150 s were usually referable to the group with the lowest professional ratings. This suggests that an engineer must be able to redirect his attention at a specific speed for successful performance, and if it exceeds the optimum range it may hinder achievement of a high level of professional skill.

If we consider that we used only engineers with a considerable work tenure on the railroad (5 to 15 years) in our experiments, we can expound another hypothesis. It refers to the fact that the speed of redirecting attention cannot always be increased to the optimum level in the course of systematic professional training.

Thus, if the speed of redirecting attention is a professionally meaningful psychological trait in an engineer, on the one hand, and it is difficult

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to develop, on the other, it must be evaluated in determining the professional fitness of engineers. Consequently, when using the described method as a test in the interests of predicting general professional achievement, individuals who scored above 150 s in the tests with the tables should be given special attention. This must be taken into consideration, first of all, in determining the desirability of continuing to use them in the occupation of engineer.

Experimental Study of Stability of Skills When There is a Shortage of Time

On the basis of analysis of performance of the operator-engineer, in our studies we proposed a method of psychological modeling directed toward examining some rather general psychophysiological traits utilized in his professional work, rather than some specific professional skills. The high coefficients of correlation between laboratory data and professional reliability, obtained in studies of different groups of engineers, revealed the significance of the different parameters studied and thereby confirmed the practical suitability of this method.

The time-related dynamic characteristics of the previously used method have not yet been defined. It is known that the speed of performance of any action may emerge as an independent condition that alleviates or complicates this activity. The question remained open as to the express requirements of speed of actions that must be made by the method in order to best demonstrate the professional fitness of an engineer, including his reserves for further increasing the speed-related aspect of his actions.

It is common knowledge that there are engineers who perform well their work at a given speed of train travel, but for whom it is very difficult or even impossible to change to higher speeds. Thus, the content- and speed-related aspects of work must be considered in reciprocal unity and their combined influence on quality of performance of the work.

The method developed previously and tested only in the speed-related mode did not furnish information about the range of speed-related capabilities of subjects. For this reason, we defined four different speed modes of tests in using the above-mentioned method.

The first was the standard mode, that had been tested before. The next three consisted of accelerating it. The operating mode in the experiment was so chosen as to find the limit of speed-related capabilities of the tested engineers. For expressly this reason, the third mode of speed created a significant shortage of time, while the fourth was assumed to be feasible by only a limited group of subjects.

While in the previously proposed variant emphasis was laid on accurate performance of individual series of control operations under standard

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conditions, in this study we concentrated on speed-related reliability of engineers as a professional factor essential to general travel safety.

Since work performed with an acute shortage of time, i.e., in a complicated situation, depends on the level of readiness for certain events, we concurrently used an additional method to test readiness for emergency action (vigilance).

We conducted a special series of experiments using the above-described method, in accordance with our objective. The basic difference between this and the preceding series was that the engineers were not tested in only one speed mode, as was the case before, but in four.

The work mode at the first speed is standard, and it was tested in the previously proposed method, and the frequency of delivery of digital signals constituted five symbols per 2 s. The subject worked for 21 min. In this time, an engineer scanned 3066 symbols. Of this total, he had to react to 882, i.e., call aloud odd numbers shown in black.

The frequency of delivery of the digits was somewhat increased in the second mode of work speed. In 13 min, the subject had to scan 2444 symbols, of which he had to single out 682 as meaningful ones. In this case, the delivery rate was 6.2 symbols per 2 s.

Working at the third rate lasted 9 min. There was a total of 2088 scanned symbols, 603 of which were meaningful. The rate of delivery of the digital signals was considerable, and it constituted 7.7/2 s.

The fourth work mode was the most difficult, and it required complete mobilization of strength and capabilities. A total of 1974 symbols had to be scanned in 7 min of work, and 567 of them had to be distinguished as meaningful. The rate of delivery was 9.4 symbols per 2 s.

Overall duration of the experiment to determine speed-related reliability was 50 min.

The shorter duration of each individual part of the experiment involving different rates is attributable to the objective difficulty of the task, which increases as one changes to the next speed.

As in the preceding test, against the background of a continuous flow of digital signals, in 50 min 20 command signals were delivered at irregular intervals, which required that the subject immediately perform a set of control actions specified in advance.

Work in all four speed modes was pursued continuously. There was a smooth transition, within 5 s, from one mode to all others.

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We tested 51 engineers with work tenure of 5 to 18 years using this method. Analysis of the experimental data consisted essentially of comparing them to the ranked order of professional characteristics. In this comparison, we used the overall average index of experimental achievement, which consists of the time and accuracy indicators of the subjects' work in all four speed modes.

The parameters were compared by the Spearman method of rank correlation.

The obtained coefficients of correlation are listed in Table 17.

Table 17.

No	Experimental parameters	1	2	3	4	5	6	7
1	Professional achievement		0.77	0.61	0.39	0.40	0.60	0.50
2	Vigilance			0.44	0.86	0.26	0.40	0.41
3	Overall reliability index				0.66	0.85	0.92	0.87
4	First speed					0.59	0.66	0.41
5	Second speed						0.79	0.69
6	Third Speed							0.80
7	Fourth speed							

The actual significance of the obtained data indicates that the parameters isolated address themselves to professional psychological traits, reflecting quite clearly their combinations and functional interrelation during work. However, the experimental results obtained with the fourth speed demonstrated convincingly that the same work is performed by the tested engineers with varying degrees of success. Some adjusted rapidly and completed the experimental series on a rather high level; others succeeded only with the first, relatively moderate work rates, while higher speeds caused great difficulties.

On the whole for the entire group, the fourth rate of work correlated less with professional achievement than the three preceding ones. Evidently, the demands it imposed were excessive for a number of engineers. But within the ranges of the first three modes, the higher the speed, the greater the correlation with professional achievement. This apparently reflects the fact that the capacity for high-speed action is a real and essential element of reliability in the work of an operator-engineer.

It became apparent in the course of these tests that it was the second, or even the third rate, rather than the first, relatively moderate one, was the most comfortable for a number of engineers.

In view of the fact, on the one hand, that there can be individual differences in subjective work rate and, on the other hand, objective

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professional requirements to be able to work at different speeds, we deemed it necessary to add to the parameters of different modes another overall index of achievement over the entire range of speeds tested. It showed a rather high correlation with professional achievement ($r = 0.61$, with $p < 0.01$).

The use of the vigilance indicator, the coefficient of correlation with professional achievement was found to be $r = 0.77$, with $p < 0.01$, was also justified. However, the above parameter correlates best with the work parameters at the first speed.

Evidently, it is desirable to conduct such tests using all four speeds for more differentiated screening. In the case of a short-term examination, it is desirable to use the third speed as being the most informative to assess the professional achievement of engineers who are engaged in railroad work at speeds of 80-120 km/h. Apparently, it is expressly the third speed that permits maximum demonstration of speed-related capabilities, that largely determine the capabilities of the operator-engineer as a whole.

The coefficients of correlation found between the selected parameters using the method we proposed indicate that this method reflects the most adequately the specific traits of an engineer that are essential to his professional activity, and it can be included in the "battery" of tests used to determine the professional fitness of applicants for engineer positions.

In view of the prospects of increasing travel speed in our country's railroad system, the possibility of changing to having one person drive a locomotive, more complicated schedules and a number of other circumstances related to development of railroad transport, we believe that scientific organization of screening of future engineers is mandatory for greater reliability of engineer work.

In our opinion, the area of psychology and psychophysiology is the section that is behind the most in theory and practice of professional screening in general and as applied to the occupation of railroad engineer in particular. While there are rather well-defined rules, methods and standards for the medicophysiological aspect of screening, psychology, as well as psychophysiology, are still far from having developed a set of standard, universal methods of examining applicants for the occupation of engineer. They have not elaborated standard-setting data that would determine whether an individual has some of the necessary prerequisites or other for successfully learning this occupation. If one so desired, it would not be difficult to list an entire series of diverse and, in some cases, really serious reasons to explain the relatively modest achievements of psychology in professional screening practice. However, no matter how valid these reasons, apparently we should discuss, first

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of all, the ones, analysis of which could help formulate some rather specific and basic tasks for psychology referable to professional work.

In our opinion, one of the most important tasks, which we have already mentioned above, consists of systemic, complex investigation of psychophysiological and psychological prerequisites for successful professional performance. In our opinion, the simplest studies and, at the same time the ones with the least promise, are those limited to testing of separate psychophysiological or psychological characteristics of man under experimental conditions specially oriented toward obtaining a result referable only to a given tested trait.

Whether it is the strength of the nervous system, memory span or something else, it is very difficult, if not impossible, to make the achievements of a subject in an experiment independent of a number of his inherent mental properties and processes, that are virtually uncontrollable by the experimenter. The experimenter has to simplify and eliminate meaningfulness from experimental activity and strive for involuntary techniques in order to evaluate the strength of the nervous system in pure form, as the primary, actually physiological characteristic of nervous activity, in order to determine memory span as its primary basic characteristic. At best, the subject is asked to perform an activity that amounts to maximum exploitation of a mental process being tested by the experimenter, in which the goal of the subject coincides with and is limited to achievement of the maximum result referable to one of its parameters: speed, accuracy, quantity, conformity with standards, etc. Within the context of the specific objectives of many psychological or psychophysiological studies, such methods are absolutely mandatory and they have yielded some extremely important information about the functional structure of mental processes, fundamental, basic characteristics of higher nervous activity in man, etc. However, many of the distinctions of laboratory methods, which are their advantages when used for the purpose they were designed, render these methods unsuitable for problems of a different nature, problems of professional screening. And we believe that it is not rational to apply them to professional screening practice without sufficient criticism.

The professional activity of a railroad engineer is a complex, diversified activity, which has its own goals the attainment of which is implemented by the use of the entire armamentarium of psychophysiological and mental phenomenon generally at man's disposal. And, of course, such an armamentarium for a specific individual may present individual distinctions manifested by the degree of expression and development of some mental traits or distinctions of higher nervous activity. Moreover, an engineer does not memorize to remember and does not strive for rapid action as a goal in itself. He must remember as many actions and perform them as rapidly as required to attain a specific result related to the general goal of safe and economical, optimum operation of the train.

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And the fact that an individual involved in a laboratory experiment, whose only goal is to respond to signals, is capable of reacting at a given speed by no means signifies that this speed will be retained in his real work and will be adequate or inadequate for successful performance. For we know that the scope and depth of predicting a situation, the accuracy of such a prediction, the emotional background and many other factors can have a substantial influence on both the speed of action and determination by the subject of the moment when they should start.

Laboratory testing of reaction speed could help us detect only rare cases of substantial deviations from the average norm. In just the same way, narrow testing of some particular property of the nervous system, for example, force of excitatory process, will furnish nothing more than knowledge about its relative expression in a given person. But for purposes of professional screening, we need to also know what real role a given property plays in a job, the performance of which implies the use of higher nervous activity with all the wealth of its properties and manifestations. Yet it is expressly testing of the strength of the nervous system with regard to excitation by the resources of specific laboratory research methods that has found rather wide use in the existing systems of professional screening.

Tests of individual psychophysiological and psychological characteristics of man by means of most existing methods are performed under conditions that are not comparable to those of real professional work, so that their findings could serve as an adequate basis for predictions of professional performance of applicants. Incidentally, we can add that it is only in exceptional cases that the duration of experiments is comparable to some extent to actual work shifts, periods of duty, etc. At the same time, it is obvious to any physiologist, psychologist or practitioner that there is a substantial change in productivity of any mental processes, of any activity when they occur over long periods of time.

Thus, the most important task presently facing psychologists who are involved with theory and practice of professional screening is to develop, test and refine basically new methods for evaluating the traits that are necessary for successful professional activity of people.

These methods should be aimed at demonstration of more integral, general traits, manifested by man's ability to perform a specific, specially designed activity under specially regulated conditions, rather than any separate psychological traits. The emphasis must be transferred from determining the degree of expression in an individual of a given mental (psychophysiological) process, phenomenon or some separate feature thereof to determination of a man's capacity to perform a specific activity. Activity that simulates the most important specific features of the psychological structure of professional activity should serve as the test activity. In this case, there will also be modeling

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of so-called "internal" conditions of professional activity in their general form. As for the external, environmental conditions, the experiment should reflect those that may have a substantial influence on mental processes, serving as interference, noise, additional useful signals, that could alter the general mode of nervous activity, requiring additional physical or nervous effort. Evidently, special thermal conditions, pronounced distinctions of the audio background, specifics of lighting, vibration, uncomfortable positions, very considerable (or, on the contrary, minimal) force applied to controls, etc., should be borne in mind as such conditions that must be taken into consideration in the experiment.

One should take into consideration exogenous conditions that, by virtue of their significant specificity, uniqueness, or intensity in a given occupation, could become a significant factor in forming the endogenous conditions of activity. At the same time, it is hardly necessary to copy purely situational, relatively incidental, irrelevant elements of conditions, or to adhere exactly to the entire set of exogenous conditions that are not beyond the range of ordinary habits that are unrelated to an occupation.

Some occupations involve the function of complex skills in executory action proper, which requires exact coordination of work done with both hands, graduation of effort, following complex trajectories, etc.

However, in simulating the psychological structure, endogenous conditions of activity, one should avoid the use of motor actions that require special training and replace it with the most elementary action that does not require learning.

If, however, the main difficulties of professional proficiency are related to development of executory motor skills, one should apparently use a series of special learning tests, in the course of which one could follow progress in learning specific, specially designed motor exercises simulating the specific distinctions of professional manipulations.

Since we were dealing with occupations involving many people and, primarily, operator professions, where the motor part of the work can be done by any physically healthy person, we did not devote any special attention to questions of formation of motor skills, although, of course, they are of independent interest and importance to the problem of professional screening.

To return to the occupation of railroad engineer, let us recall that we tried to design a method that would diagnose the professional reliability of engineers on the basis of tests that schematically simulate the psychological structure of the engineer's professional activity.

To avoid any possible misunderstandings, it should be stated that the general approach that we propose for designing methods of determining

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professional fitness by no means signify that we abandon demonstration of psychological prerequisites and mechanisms of professional fitness. Rather, this is a necessary step in studying such prerequisites, taken in their actual complex and mutually determined form, in their systemic, functional unity. A comparison of the results of traditional tests, which demonstrate the levels of different mental traits of man, to quality of performance simulating professional work and to the quality of actual professional work shows that this is a rather promising route, and it helps formulate new hypotheses and research objectives. Modeling of the psychological structure of performance itself implies the existence of comprehensive preliminary work dealing with analysis of the real activity of a professional, demonstration of the main difficulties, their psychological causes and studies of working conditions. Analysis of the psychological structure of performance can be made on the level of different structural units and in different aspects. We have proposed an aspect of analysis of the system used in the activity of a professional, its voluntary goal-oriented regulation. And the "functional element" of the regulatory system emerged as the analytical unit, i.e., the component of the regulation process that performs its own special function in it. Depending on the specific distinctions of different occupations, the process of regulation of performance may have its own specific distinctions also, which are manifested by the degree of structural perfection of this process, the specific interrelations between its functional elements. In Chapter 2, we described in detail the general model of a structurally perfect system of self-regulation of voluntary activity, which was used to analyze engineer performance. In the belief that the aspect of voluntary regulation of activity is quite promising, with respect to solving a number of problems of psychology of work activity, in particular, to designing methods of professional screening, we also reiterate that there can be a multitude of aspects of analysis of activity and approaches to the design of experiments to test the general psychological prerequisites for successful professional performance. We consider the aspect that we propose as being only one of the possible ones.

No matter how correctly preliminary professional screening is performed and no matter how good the choice of specific applicants for a given occupation, the reliability of professional performance as its most important and mandatory trait is the product of formation of performance. For this reason, another range of problems of utmost importance pertaining to reliability of the engineer's performance is related to the problem of vocational education and advanced professional training.

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CHAPTER 6. CHARACTERISTICS OF MODERN LOCOMOTIVE SIMULATORS

Moscow INZHENERNAYA PSIKHOLOGIYA I PROBLEMA NADEZHNOСТИ MASHINISTA in Russian 1978 signed to press 25 Aug 78 pp 206-209

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[Text] We have briefly discussed the essential psychological requirements for the design of simulators, classification thereof and grounds for using them in driver professions. It should be noted that simulators began to be used for driver professions long before psychological theory of simulators was expounded, and they were used for vocational training with some degree of benefit. The simulator was a means of training, often used primarily to become acquainted with the operating principles of some technical system or other, or with the methods of working on it, i.e., as a graphic aid. However, the very first attempts at using simulators to develop and secure driving skills in young operators with short work tenure revealed that they not only enhanced the visual aspect of training, but reduced significantly its duration (which has important social and economic consequences), as well as improved the level of professional training of operators. Special studies conducted in the United States established that the use of simulators reduces total time for practical training by 50% and increases significantly the quality of the teaching process and its results. Such findings prompted considerable practical interest, and led to numerous engineering and design developments in this field. There was an increase in number of simulators for the railroad as well, with appearance of special enterprises specializing in the manufacture of simulators, for example, General Precision System General Company in Great Britain and Brown Boveri Company in Switzerland, etc.

Modern railroad simulators are complex systems of electronic equipment with programming devices and computers, which simulate the dynamics of the controlled object as a whole and its individual structural elements, control of these objects by means of special equipment.

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Railroad simulators are intended not only for practical training or re-training of engineers, but for the needs of transport medicine, physiology and psychology, i.e., they can be used effectively for scientific purposes as unique experimental devices.

Most often, the simulator consists of a cab or model of engineer's cab, equipped with a controller, brake valve, control console with buttons, handles, control levers and measuring instruments. Instead of a windshield, there is a special screen on which a film is projected of a specific segment of road, or slides of specific road situations.

When the film is screened, the individual in the simulator cab has the same sensations as he would in a locomotive traveling over a section of the line. This is achieved because the speed of movement of the image is linked with locomotive controls or a computer that sets the movement program, and it is proportionate to "traveling speed." The mode of "engine" operation also changes in accordance with the position of the instruments.

The color signals can be delivered to the locomotive cab by either an instructor or programming device, and they conform strictly with the color of the road signals photographed on the film.

There is a special suspension device or vibration table to simulate jolting, vibration, and acceleration on curved segments of the road. There is also reproduction of most of the noises present during actual work and typical sounds when "passing" on bridges and overpasses.

The computer, or console that controls training, is the central device of the simulator, it maintains operation of all machinery and instruments of the simulator, sets and changes their readings.

The training process can be implemented by either an instructor following a free program, or a programming device following a preset program that provides for complex operating modes corresponding to emergency situations. A number of devices include automatic recording of actions and psychophysiological parameters of the trainee during the driving process.

Such simulators have been designed on a number of railroads in our country. In particular, simulators corresponding to the models described have been designed at the Leningrad Institute of Railroad Transportation Engineers (simulator that permits testing at speeds of up to 200 km/h), in the laboratory of ergonomics at Kuybyshev Institute of Railroad Transportation Engineers, at the planning and design office of the Main Administration of Locomotives, etc.

All of these simulators are either complex installations, or installations designed to learn driving skills. In addition, specialized simulators

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are being developed, which are designed to develop skill in detecting malfunctions in the locomotive power plant.

Such simulators are used at the Leningrad-Moscow locomotive depot of the Oktyabr'skaya Line, Penza locomotive depot of the Kuybyshev line, Zaslauks depot of the Baltic line, etc.

According to their description, these simulators make it possible to pursue comprehensive studies of existing power plants of modern electric locomotives of the VL10, ChS2, etc., types, their electrical circuitry, as well as methods of detecting and correcting defects in different units. They consist of a functional mock-up of the electrical circuit of a specific electric locomotive. All of the instruments and apparatus are either taken entirely from the specific locomotives, or else are constructed the same in type and size as the real instruments and apparatus, and they are arranged in the same order as on electric locomotives. The operation of instruments and electric circuits conforms entirely with that of their prototypes, which permits practical training of locomotive crews under conditions that are close to real ones.

The instructor-engineer can "program" a specific malfunction in the electric circuitry by means of a special [switch?] board and ask the trainee to detect and eliminate the damage within a strictly specified time. Experience with such a simulator on the Oktyabr'skaya line revealed that it not only helps gain better proficiency, but reduces expenditure of electricity by the crews that were trained on it. Substantial differences were found in savings of power between trained and untrained (on this simulator) engineers.

In the opinion of the creators of this simulator, it can be used for the practical training of locomotive crews using progressive methods of running passenger trains at speeds of 120-160 km/h.

Analysis of simulators with different systems, which were developed on USSR railroads and described in the foreign literature, leads us to conclude that these systems largely conform with the goals of professional training; however, they are not very suitable for training engineers under critical working conditions. This is attributable to the fact that the simulators we have discussed have some substantial design and operating limitations.

Design flaws include the fact that the individual in the simulator cab either fails to receive immediate information about his progress, or else this information is incomplete and inadequate. In other words, there is no constant feedback for the trainee, and he is deprived of the possibility of conscious self-checking of his actions as he performs them. Yet such immediate information about accuracy and time characteristics of performance is necessary in order to make the appropriate corrections in performance and aids in automation of skill.

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The operating flaws include the following: lack of clearcut programs for developing work skills in emergency situations, nor is there agreement as to which emergency situations should be worked on and what speeds should be used in training for best mastery of skills; failure to adhere to the main psychological requirements listed before in a number of designs of Soviet and foreign simulators.

The chief cause of the flaws we have mentioned is that there is no sufficiently developed system of psychological requirements for the design and use of simulators.
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